Synapse
Energy Economics, Inc.

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PROFESSIONAL EXPERIENCE

Synapse Energy Economics Inc., Cambridge, MA. *Associate*, January 2018 – Present

Conducts research and provides consulting on energy sector issues. Examples include:

- modeling for resource planning using PLEXOS utility planning software, analysis of system-level cost impacts of energy efficiency nationwide;
- rate design for distributed energy resources within the state of Hawaii; and
- developing a manual and providing quality control for a tool to analyze the impacts of climate measures and energy policies in Morocco.

Rocky Mountain Institute, Basalt, CO. August 2012 – September 2017

Senior Associate

- Led technical analysis, modeling, training and capacity building work for utilities and governments in Sub-Saharan Africa around integrated resource planning for the central electricity grid energy and identified over a billion dollars in savings based on improved resource-planning processes.
- Represented RMI as a content expert and presented materials on electricity pricing and rate design at conferences and events.
- Led a project to research and evaluate utility resource planning and spending processes, focusing specifically on integrated resource planning, to highlight systematic overspending on conventional resources and underinvestment and underutilization of distributed energy resources as a least-cost alternative.

Associate

- Led modeling analysis in collaboration with NextGen Climate America which identified a CO_2 loophole in the Clean Power Plan of 250 million tons, or 41 percent of EPA projected abatement, and was submitted as an official federal comment, and led to a modification to address the loophole in the final rule.
- Led financial and economic modeling in collaboration with a major U.S. utility to quantify the impact that solar PV would have on their sales, and helped them identify alternative business models that would allow them to recapture a significant portion of this at-risk value.

- Supported the planning, content development, facilitation, and execution of numerous events and workshops with participants from across the electricity sector for RMI's Electricity Innovation Lab (eLab) initiative.
- Co-authored two studies reviewing valuation methodologies for solar PV and laying out new principles and recommendations around pricing and rate design for a distributed energy future in the United States. These studies have been highly cited by the industry and submitted as evidence in numerous Public Utility Commission rate cases.

The University of Michigan, Ann Arbor, MI. *Graduate Student Instructor*, September 2011 – July 2012

Prepared lesson plans, taught classes, graded papers and other coursework, met regularly with students.

The Virginia Sea Grant at the Virginia Institute of Marine Science, Gloucester Point, VA. *Policy Intern*, Summer 2011

Managed a communication network analysis study of coastal resource management stakeholders on the Eastern Shore of the Delmarva Peninsula.

The Commission for Environmental Cooperation (NAFTA), Montreal, QC. *Short Term Educational Program/Intern*, Summer 2010

Researched energy and climate issues relevant to the NAFTA parties to assist the executive director in conducting a GAP analysis of emission monitoring, reporting, and verification systems in North America.

Congressman Tom Allen, Portland, ME. *Technology Systems and Outreach Coordinator*, August 2007 – December 2008

Directed Congressman Allen's technology operation, responded to constituent requests, and represented the Congressman at events throughout southern Maine.

EDUCATION

The University of Michigan, Ann Arbor, MI
Master of Public Policy, Gerald R. Ford School of Public Policy, 2012
Master of Science, School of Natural Resources and the Environment, 2012
Masters Project: *Climate Change Adaptation Planning in U.S. Cities*

Middlebury College, Middlebury, VT
Bachelor of Arts, 2007
Environmental Studies, Policy Focus; Minor in Spanish
Thesis: *Environmental Security in a Changing National Security Environment: Reconciling Divergent Policy Interests, Cold War to Present*

PUBLICATIONS

Fagan, B., R. Wilson, S. Fields, D. Glick, D. White. 2018. *Nova Scotia Power Inc. Thermal Generation Utilization and Optimization: Economic Analysis of Retention of Fossil-Fueled Thermal Fleet To and Beyond 2030 – M08059*. Prepared for Board Counsel to the Nova Scotia Utility Review Board.

Ackerman, F., D. Glick, T. Vitolo. 2018. *Report on CCR proposed rule*. Prepared for Earthjustice.

Lashof, D. A., D. Weiskopf, D. Glick. 2014. *Potential Emission Leakage Under the Clean Power Plan and a Proposed Solution: A Comment to the US EP*A. NextGen Climate America.

Smith, O., M. Lehrman, D. Glick. 2014. *Rate Design for the Distribution Edge*. Rocky Mountain Institute.

Hansen, L., V. Lacy, D.Glick. 2013. *A Review of Solar PV Benefit & Cost Studies*. Rocky Mountain Institute.

TESTIMONY

Public Service Commission of South Carolina (Docket No. 2018-2-E): Direct testimony of Devi Glick on avoided cost calculations and the costs and benefits of solar net energy metering. On behalf of South Carolina Coastal Conservation League and Southern Alliance for Clean Energy. April 12, 2018.

Public Service Commission of South Carolina (Docket No. 2018-2-E): Surrebuttal testimony of Devi Glick on avoided cost calculations and the costs and benefits of solar net energy metering. On behalf of South Carolina Coastal Conservation League and Southern Alliance for Clean Energy. April 4, 2018.

Resume updated May 2018

Electricity Innovation Lab
ROCKY MOUNTAIN INSTITUTE

A REVIEW OF SOLAR PV BENEFIT & COST STUDIES

2nd Edition

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2nd Edition, published September 2013
download at: www.rmi.org/elab_emPower

ABOUT THIS DOCUMENT

This report is a 2nd edition released in September 2013. This second edition updates the original with the inclusion of Xcel E **Costs and Benefits of Distributed Solar Generation on the Public Service Company of Colorado*****, as well as clarifies select de***

TABLE OF CONTENTS

OBJECTIVE AND ACKNOWLEDGEMENTS

The objective of this e-Lab discussion document is to assess what is known and unknown about the categorization, methodological best practices, and gaps around the benefits and costs of distributed photovoltaics (DPV), and to begin to establish a clear foundation from which additional work on benefit/cost assessments and pricing structure development can be built.

Building on initial research conducted as part of Rocky Mountain Institute's (RMI) DOE SunShot funded project, Innovative Solar Business Models, this e-Lab work product was prepared by RMI to support e-Lab and industry-wide discussions about distributed energy resource valuation. e-Lab is a joint collaboration, convened by RMI, with participation from stakeholders across the electricity industry. e-Lab is not a consensus organization, and the views expressed in this document do not necessarily represent those of any individual e-Lab member or supporting organizations. Any errors are solely the responsibility of RMI.

e-Lab members and advisors were invited to provide input on this report. The assessment greatly benefited from contributions by the following individuals: Stephen Frantz, Sacramento Municipal Utility District (SMUD); Mason Emnett, Federal Energy Regulatory Commission (FERC); Eran Mahrer, Solar Electric Power Association (SEPA); Sunil Cherian, Spirae; Karl Rabago, Rabago Energy; Tom Brill and Chris Yunker, San Diego Gas & Electric (SDG&E); and Steve Wolford, Sunverge.

WHAT IS e-LA

The Electricity I
together thought
from across the U
critical instituti
economic, and te
deployment of dis

In particular, e-La
questions:

- How can w
communicat
distributed r
electricity sy
flexibility?

- How can w
frameworks
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customers a

- How can w
economic d

A multi-year prog
its members to id
solutions to the
questions. e-Lab
coupled with ong
and supported b
Lab meetings allo
best practices, a
around key issue
dives into researc

EXECUTIVE SUMMARY

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EXECUTIVE SUMMARY

THE NEED

- The addition of distributed energy resources (DERs) onto the grid creates new opportunities and challenges because of their unique siting, operational, and ownership characteristics compared to conventional centralized resources.

- Today, the increasingly rapid adoption of distributed solar photovoltaics (DPV) in particular is driving a heated debate about whether DPV creates benefits or imposes costs to stakeholders within the electricity system. But the wide variation in analysis approaches and quantitative tools used by different parties in different jurisdictions is inconsistent, confusing, and frequently lacks transparency.

- Without increased understanding of the benefits and costs of DERs, there is little ability to make effective tradeoffs between investments.

OBJECTIVE OF THIS DOCUMENT

- The objective of this e-Lab discussion document is to assess what is known and unknown about the categorization, methodological best practices, and gaps around the benefits and costs of DPV, and to begin to establish a clear foundation from which additional work on benefit/cost assessments and pricing structure design can be built.

- This discussion document reviews 16 DPV benefit/cost studies by utilities, national labs, and other organizations. Completed between 2005 and 2013, these studies reflect a significant range of estimated DPV value.

KEY INSIGHTS

- No study comprehensively evaluated the DPV, although many acknowledge additi cost and many agree on the broad categ There is broad recognition that some ben difficult or impossible to quantify, and so stakeholders.

- There is a significant range of estimated driven primarily by differences in local co assumptions, and methodological appro

    - **Local context**: Electricity system ch mix, demand projections, investmen —vary across utilities, states, and reg
    - **Input assumptions**: Input assumptio forecasts, solar power production, p can vary widely.
    - **Methodologies**: Methodological diff significantly affect results include (1) and granularity of data, (2) assumed categories and stakeholder perspect approaches to calculating individual

- Because of these differences, comparin can be informative, but should be done that results must be normalized for con methodology.

- While detailed methodological differenc general agreement on overall approach value and some philosophical agreeme although there remain key differences i There is significantly less agreement on estimating grid support services and cu values including financial and security r social value.

EXECUTIVE SUMMARY (CONT'D)

IMPLICATIONS

- Methods for identifying, assessing and quantifying the benefits and costs of DPV and other DERs are advancing rapidly, but important gaps remain to be filled before this type of analysis can provide an adequate foundation for policymakers and regulators engaged in determining levels of incentives, fees, and pricing structures for DPV and other DERs.

- In any benefit/cost study, it is critical to be transparent about assumptions, perspectives, sources and methodologies so that studies can be more readily compared, best practices developed, and drivers of results understood.

- While it may not be feasible to quantify or assess sources of benefit and cost comprehensively, benefit/cost studies must explicitly decide if and how to account for each source of value and state which are included and which are not.

- While individual jurisdictions must adapt approaches based on their local context, standardization of categories, definitions, and methodologies should be possible to some degree and will help ensure accountability and verifiability of benefit and cost estimates that provide a foundation for policymaking.

- The most significant methodological gaps include:

  - **Distribution value:** The benefits or costs that DPV creates in the distribution system are inherently local, so accurately estimating value requires much more analytical granularity and therefore greater difficulty.
  - **Grid support services value:** There continues to be uncertainty around whether and how DPV can provide or require additional grid support services, but this could potentially become an increasingly important value.
  - **Financial, security, environmental, and social values:** These values are largely (though not comprehensively) unmonetized as part of the electricity system and some are very difficult to quantify.

LOOKING AHEAD

- Thus far, studies have made simplifying as implicitly assume historically low penetratio penetration of DPV on the electric system sophisticated, granular analytical approach and the total value is likely to change.

- Studies have largely focused on DPV by its of factors is likely to drive increased adopt spectrum of renewable and distributed res consideration of DPV's benefits and costs changing system.

- With better recognition of the costs and be can create, including DPV, pricing structure models can be better aligned, enabling gre deployment of these resources and lower c for ratepayers.

FRAMING THE NEED

01

overview

distributed energy resources

structural misalignments

structural misalignments in practice

FRAMING THE NEED

- A confluence of factors including rapidly falling solar prices, supportive policies, and new approaches to finance are leading to a steadily increasing solar PV market.
    - In 2012, the US added 2 GW of solar PV to the nation's generation mix, of which approximately 50% were customer-sited solar, net-metered projects.[1]
    - Solar penetrations in certain regions are becoming significant. About 80% of customer-sited PV is concentrated in states with either ample solar resource and/or especially solar-friendly policies: California, New Jersey, Arizona, Hawaii and Massachusetts.[2]
- The addition of DPV onto the grid creates new challenges and opportunities because of its unique siting, operational, and ownership characteristics compared to conventional centralized resources. The value of DPV is temporally, operationally and geographically specific and varies by distribution feeder, transmission line configuration, and composition of the generation fleet.
- Under today's regulatory and pricing structures, multiple misalignments along economic, social and technical dimensions are emerging. For example, in many instances pricing mechanisms are not in place to recognize or reward service that is being provided by either the utility or customer.
- Electricity sector stakeholders around the country are recognizing the importance of properly valuing DPV and the current lack of clarity around the costs and benefits that drive DPV's value, as well as how to calculate them.
- To enable better technical integration and economic optimization, it is critical to better understand the services that DPV can provide and require, and the benefits and costs of those services as a foundation for more accurate pricing and market signals. As the penetration of DPV and other customer-sited resources increases, accurate pricing and market signals can help align stakeholder goals, minimize total system cost, and maximize total net value.

Photo courtesy of Shutterstock

1. Solar Electric Power Association. June 2013. *2012 SEPA Utility Solar Rankings,* Washington, DC.
2. Ibid.

DPV IN THE BROADER CONTEXT OF DISTRIBUTED ENERGY RESOURCES

DISTRIBUTED ENERGY RESOURCES (DERs): demand- and supply-side resources that can be deployed throughout an electric dis
the energy and reliability needs of the customers served by that system. DERs can be installed on either the customer side or the utility side o

TYPES OF DERs:

Efficiency

Technologies and behavioral changes that reduce the quantity of energy that customers need to meet all of their energy-related needs.

Distributed generation

Small, self-contained energy sources located near the final point of energy consumption. The main distributed generation sources are:

- Solar PV
- Combined heat & power (CHP)
- Small-scale wind
- Others (i.e., fuel cells)

Distributed flexibility & storage

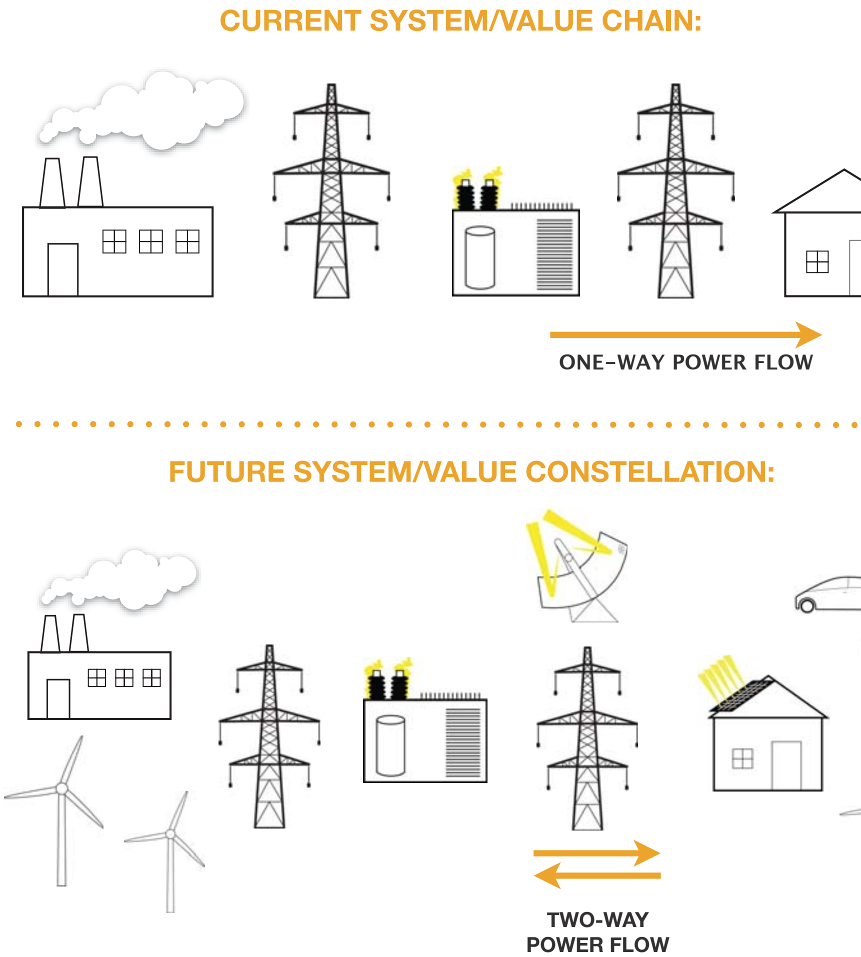
A collection of technologies that allows the overall system to use energy smarter and more efficiently by storing it when supply exceeds demand, and prioritizing need when demand exceeds supply. These technologies include:

- Demand response
- Electric vehicles
- Thermal storage
- Battery storage

Distributed intelligence

Technologies that combine sensory, communication, and control functions to support the electricity system, and magnify the value of DER system integration. Examples include:

- Smart inverters
- Home-area networks
- Microgrids

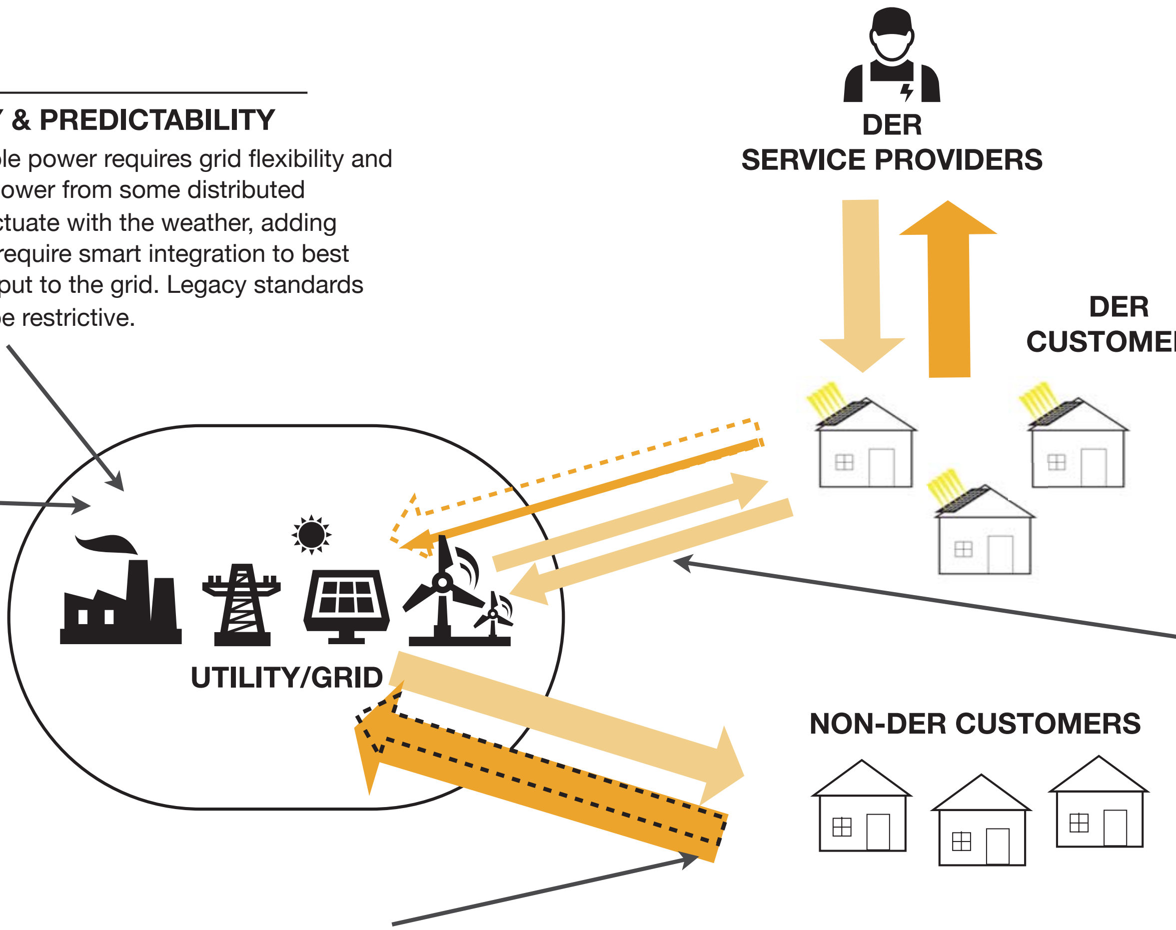


STRUCTURAL MISALIGNMENTS

TODAY, OPERATIONAL AND PRICING MECHANISMS DESIGNED FOR AN HISTORICALLY CENTRALIZED SYSTEM ARE NOT WELL-ADAPTED TO THE INTEGRATION OF DERS, CAUSING FRICTION AND INEFFIC

FLEXIBILITY & PREDICTABILITY
Providing reliable power requires grid flexibility and predictability. Power from some distributed renewables fluctuate with the weather, adding variability, and require smart integration to best shape their output to the grid. Legacy standards and rules can be restrictive.

LOCATION & TIME
Limited feedback loop to customers that the costs or benefit of any electricity resource, especially DERs, vary by location and time.



SOCIAL PRIORITIES
Society values the environmental and social benefits that DERs could provide, but those benefits are often externalized and unmonetized.

SOCIAL EQUITY
If costs are incurred by DER customers that are not paid for, those costs would be allocated to the rest of customers. Conversely, DER customers also provide benefits to other customers and to society.

Adapted from RMI, Net Energy Metering, Zero Net Energy And The Distributed Energy Resource Future: Adapting Electric Utility Business Models For The 21st Century

STRUCTURAL MISALIGNMENTS IN PRACT

THESE STRUCTURAL MISALIGNMENTS ARE LEADING TO IMPORTANT QUESTIONS, DEBATE, AND CO

VALUE UNCERTAINTY...

$/YEAR

TRADITIONAL COST TO SERVE

CUSTOMER BILL

WHAT IF A DPV CUSTOMER DOES NOT PAY FOR THE FULL COST TO SERVE THEIR DEMAND?

COST TO SERVE

CUSTOMER BILL

WHAT IF A DPV CUSTOMER IS NOT FULLY COMPENSATED FOR THE SERVICE THEY PROVIDE?

COST TO SERVE

CUSTOMER BILL

Customer Payment
Generation Cost
Distribution Cost
Transmission Cost
Other Costs

...DRIVES HEADLINES...

...R QU

- What b provide custom conting
- What c suppor
- What a method benefit
- How sh unmon enviror benefit
- How ca more e priced

SETTING THE STAGE

02

defining value
categories of value
stakeholder implications

SETTING THE STAGE

- When considering the total value of DPV or any electricity resource, it is critical to consider the types of value, the stakeholder perspective and the flow of benefits and costs–that is, who incurs the costs and who receives the benefits (or avoids the costs).

- For the purposes of this report, value is defined as net value, i.e. benefits minus costs. Depending upon the size of the benefit and the size of the cost, value can be positive or negative.

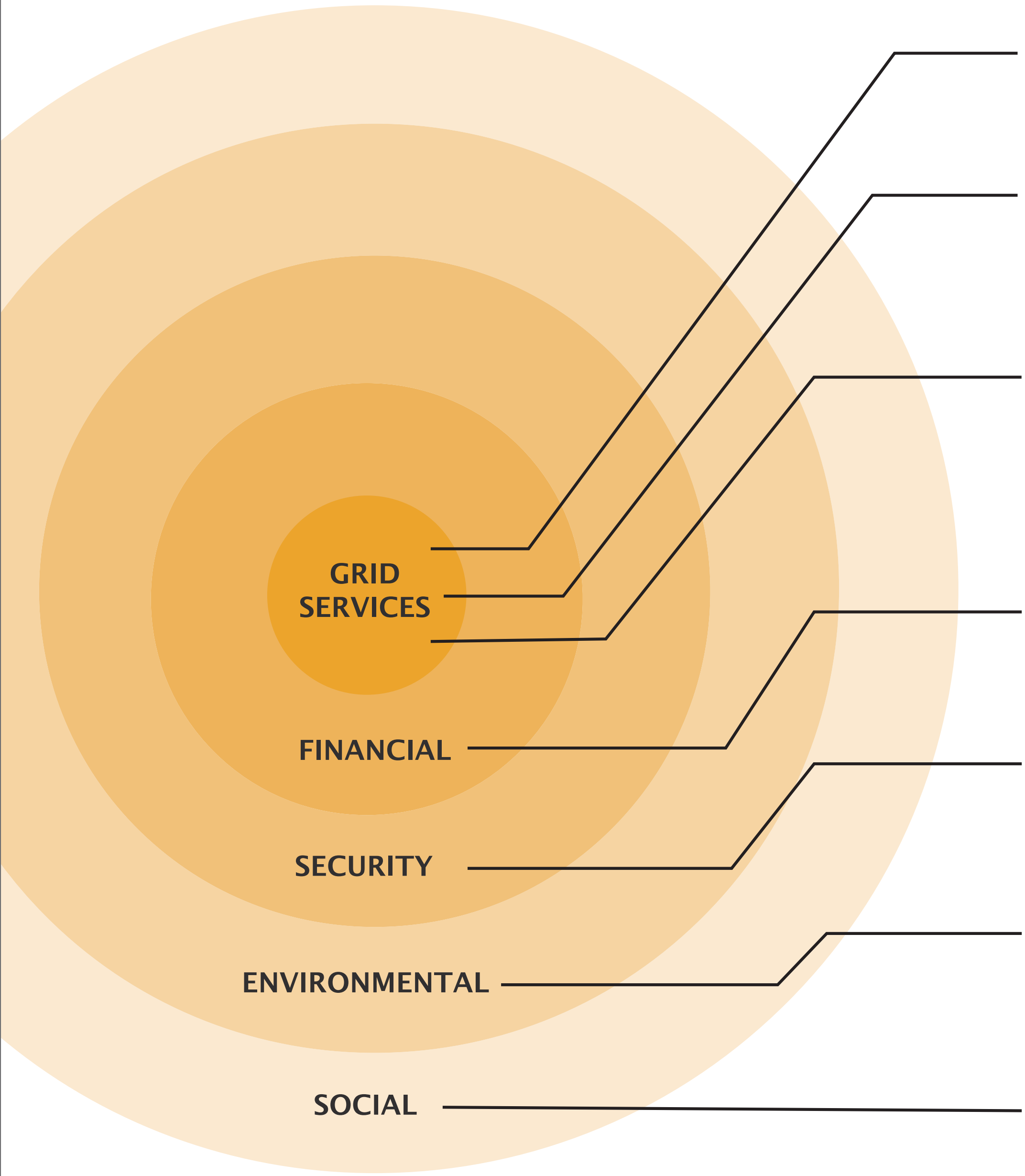
- A variety of categories of benefits or costs of DPV have been considered or acknowledged in evaluating the value of DPV. Broadly, these categories are: energy, system losses, capacity (generation, transmission and distribution), grid support services, financial risk, security risk, environmental and social.

- These categories of costs and benefits differ significantly by the degree to which they are readily quantifiable or there is a generally accepted methodology for doing so. For example, there is general agreement on overall approach to estimating energy value and some philosophical agreement on capacity value, although there remain key differences in capacity methodology. There is significantly less agreement on overall approach to estimating grid support services and currently unmonetized values including financial and security risk, environment, and social value.

- Equally important, the qualification of whether a factor is a benefit or cost also differs depending upon the perspective of the stakeholder. Similar to the basic framing of testing cost effectiveness for energy efficiency, the primary stakeholders in calculating the value of DPV are: the participant (the solar customer); the utility; other customers (also referred to as ratepayers); and society (taxpayers are a subset of society).

BENEFIT & COST CATEGORIES

For the purposes of this report, **value is defined as net value, i.e. benefits minus costs.** Depending upon the size of the
value can be positive or negative. A variety of categories of benefits or costs of DPV have been considered or acknowledg
DPV. Broadly, these categories are:



ENERGY
- energy
- system losses

CAPACITY
- generation capacity
- transmission & distribution capacity
- DPV installed capacity

GRID SUPPORT SERVICES
- reactive supply & voltage control
- regulation & frequency response
- energy & generator imbalance
- synchronized & supplemental operating re
- scheduling, forecasting, and system contr

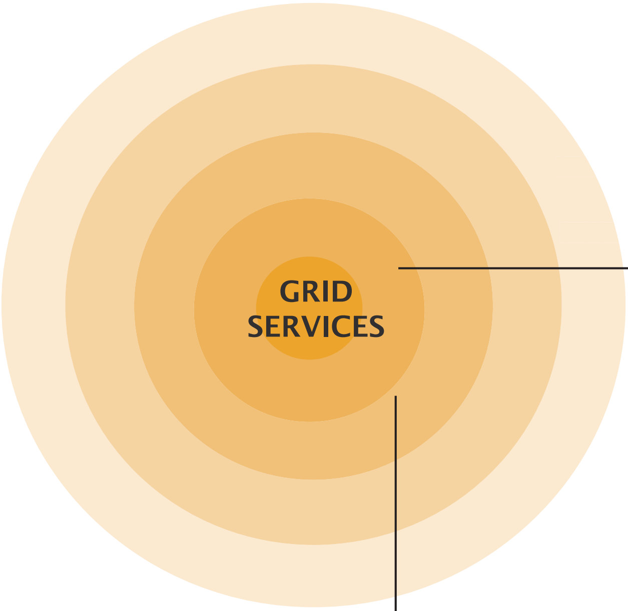
FINANCIAL RISK
- fuel price hedge
- market price response

SECURITY RISK
- reliability & resilience

ENVIRONMENTAL
- carbon emissions (CO_2)
- criteria air pollutants (SO_2, NO_x, PM)
- water
- land

SOCIAL
- economic development (jobs and tax reve

BENEFIT & COST CATEGORIES DEFINED



ENERGY

Energy value of DPV is positive when the solar energy generated displac
from another resource at a net savings. There are two primary compone

- **Avoided Energy** - The cost and amount of energy that would ha
to meet customer needs, largely driven by the variable costs of the
displaced. In addition to the coincidence of solar generation with c
drivers of avoided energy cost include (1) fuel price forecast, (2) va
maintenance costs, and (3) heat rate.

- **System Losses** - The compounded value of the additional energ
that would otherwise be lost due to inherent inefficiencies (electric
energy to the customer via the transmission and distribution syste
energy at or near the customer, those losses are avoided. Losses a
capacity and environmental benefits, since avoided energy losses
capacity and lower emissions.

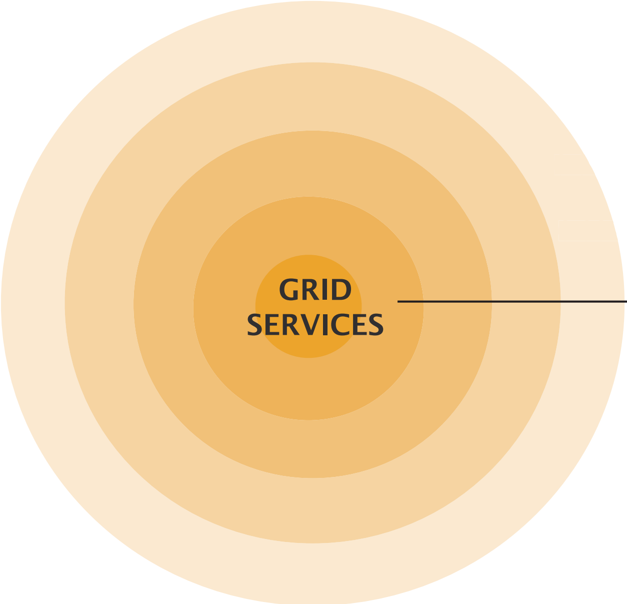
CAPACITY

Capacity value of DPV is positive when the addition of DPV defers or avo
generation, transmission, and distribution assets than it incurs. There are

- **Generation Capacity** - The cost of the amount of central genera
deferred or avoided due to the addition of DPV. Key drivers of value
capacity and (2) system capacity needs.

- **Transmission & Distribution Capacity** - The value of the net ch
investment due to DPV. Benefits occur when DPV is able to meet ri
capacity constraints upstream and deferring or avoiding T&D upgra
additional T&D investment is needed to support the addition of DP

BENEFIT & COST CATEGORIES DEFINED



GRID SUPPORT SERVICES

Grid support value of DPV is positive when the net amount and cost of
to balance supply and demand is less than would otherwise have been
services, which encompass more narrowly defined ancillary services (A
to enable the reliable operation of interconnected electric grid systems.
include:

- **Reactive Supply and Voltage Control**— Generation facilities usec
  and voltage control.

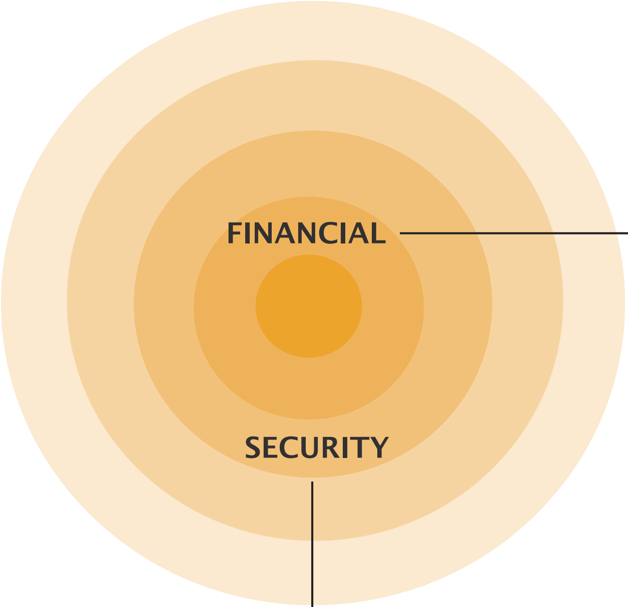
- **Frequency Regulation**—Control equipment and extra generating
  maintain frequency by following the moment-to-moment variations
  (supplying power to meet any difference in actual and scheduled g
  automatically to frequency deviations in their networks. While the s
  regulation service and frequency response service are different, the
  services made available using the same equipment and are offerec

- **Energy Imbalance**—This service supplies any hourly net mismatc
  supply and the actual load served.

- **Operating Reserves**—Spinning reserve is provided by generating
  loaded at less than maximum output, and should be located near t
  control area). They are available to serve load immediately in an ur
  Supplemental reserve is generating capacity used to respond to co
  not available instantaneously, but rather within a short period, and
  load (typically in the same control area).

- **Scheduling/Forecasting**—Interchange schedule confirmation anc
  control areas, and actions to ensure operational security during the

BENEFIT & COST CATEGORIES DEFINED



FINANCIAL RISK

Financial value of DPV is positive when financial risk or overall market pr
the addition of DPV. Two components considered in the studies reviewed

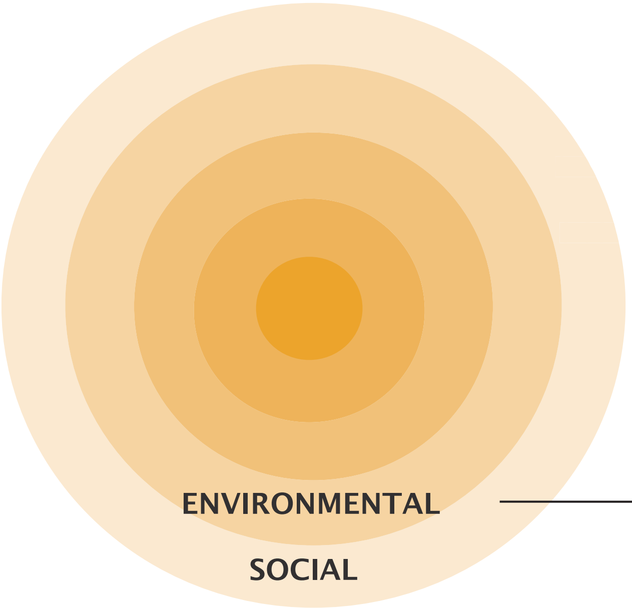
- **Fuel Price Hedge** - The cost that a utility would otherwise incur
portion of electricity supply costs are fixed.

- **Market Price Response** - The price impact as a result of DPV's
centrally-supplied electricity and the fuel that powers those genera
lowering electricity prices and potentially commodity prices.

SECURITY RISK

Security value of DPV is positive when grid reliability and resiliency are in
reducing outages by reducing congestion along the T&D network, (2) red
outages by increasing the diversity of the electricity system's generation
smaller generators that are geographically dispersed, and (3) providing b
sources available during outages through the combination of PV, control
inverters and storage.

BENEFIT & COST CATEGORIES DEFINED



ENVIRONMENTAL

Environmental value of DPV is positive when DPV results in the reductio
health impacts that would otherwise have been created. Key drivers inc
environmental impacts of the marginal resource being displaced. There
environmental value:

- **Carbon** - The value from reducing carbon emissions is driven b
of displaced marginal resource and the price of emissions.

- **Criteria Air Pollutants** - The value from reducing criteria air pol
SO_2, and particulate matter—is driven by the cost of abatement te
value of pollutant reductions, and/or the cost of human health dar

- **Water** - The value from reducing water use is driven by the diffe
patterns associated with different generation technologies, and is
the price paid for water in competing sectors.

- **Land** - The value associated with land is driven by the differenc
required for energy generation and any change in property value c
DPV.

- **Avoided Renewable Portfolio Standard costs (RPS)** - The val
electricity demand through DPV, which reduces total demand that
be met and the associated renewable energy that would have to b
by an RPS.

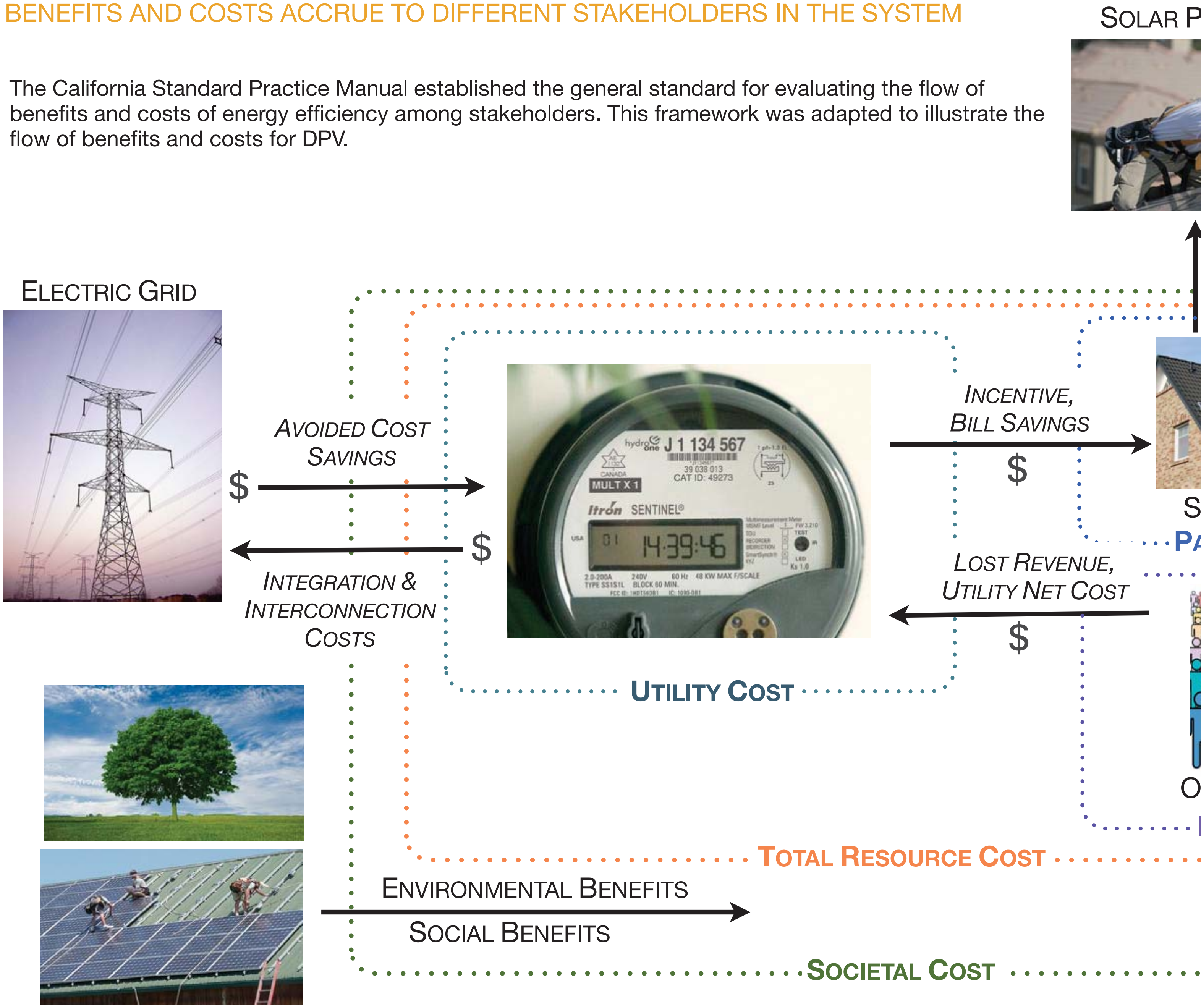
SOCIAL

The studies reviewed in this report defined social value in economic terr
DPV was positive when DPV resulted in a net increase in jobs and local
Key drivers include the number of jobs created or displaced, as measur
well as the value of each job, as measured by average salary and/or tax

FLOW OF BENEFITS AND COSTS

BENEFITS AND COSTS ACCRUE TO DIFFERENT STAKEHOLDERS IN THE SYSTEM

The California Standard Practice Manual established the general standard for evaluating the flow of benefits and costs of energy efficiency among stakeholders. This framework was adapted to illustrate the flow of benefits and costs for DPV.



STAKEHOLDER PERSPECTIVES

stakeholder perspective		factors affecting value
PV CUSTOMER 	"I want to have a predictable return on my investment, and I want to be compensated for benefits I provide."	Benefits include the reduction in the customer's utility bill, any in utility or other third parties, and any federal, state, or local tax cr include cost of the equipment and materials purchased (inc. tax O&M, removal costs, and the customer's time in arranging the in
OTHER CUSTOMERS 	"I want reliable power at lowest cost."	Benefits include reduction in transmission, distribution, and gene energy costs and grid support services. Costs include administra incentives, and decreased utility revenue that is offset by increas
UTILITY 	"I want to serve my customers reliably and safely at the lowest cost, provide shareholder value and meet regulatory requirements."	Benefits include reduction in transmission, distribution, and gene energy costs and grid support services. Costs include administr incentives, decreased revenue, integration & interconnection cos
SOCIETY 	"We want improved air/water quality as well as an improved economy."	The sum of the benefits and costs to all stakeholder, plus any ac environmental benefits or costs that accrue to society at large ra stakeholder.

ANALYSIS FINDINGS

analysis overview

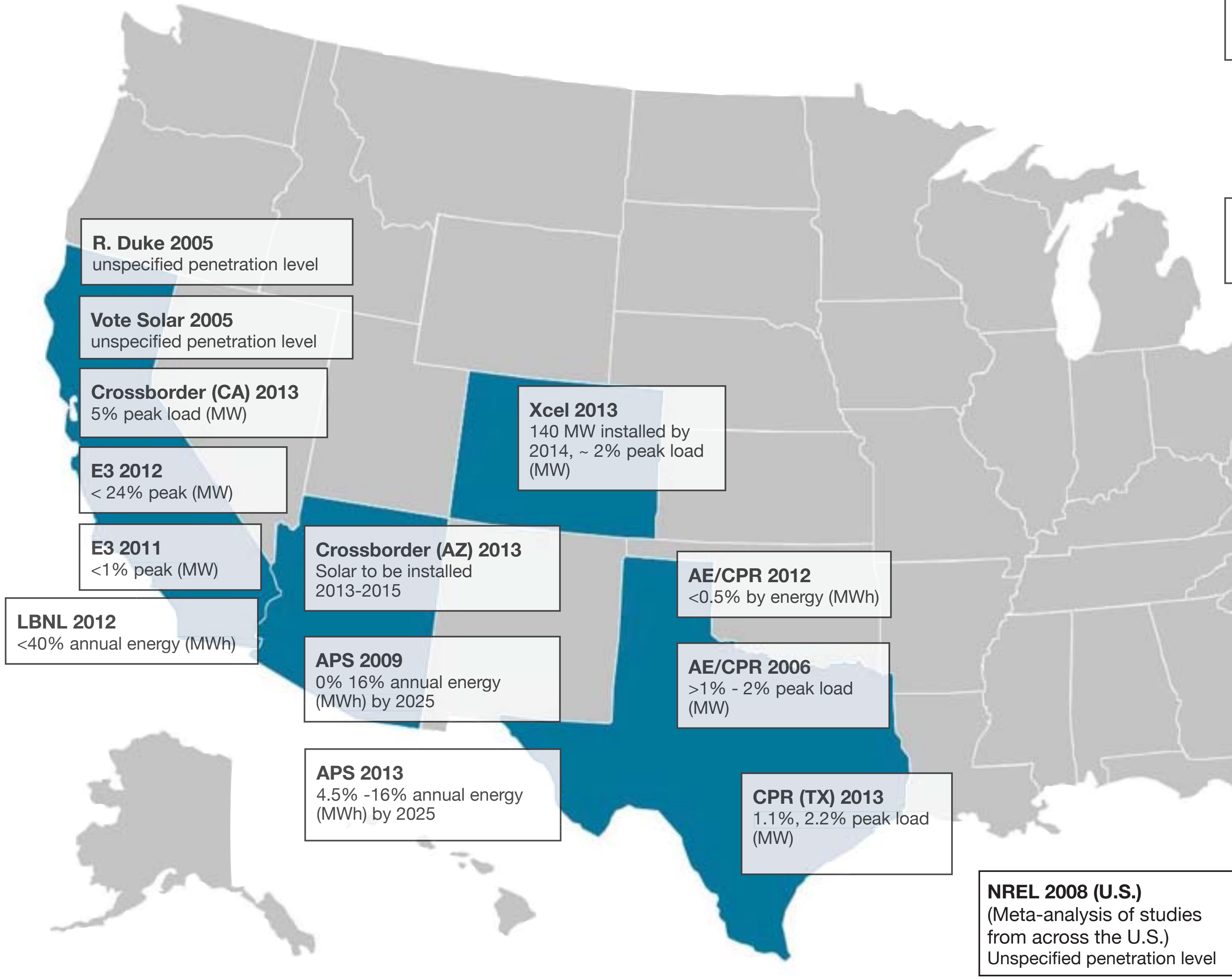
summary of benefits and costs

detail: categories of benefit and cost

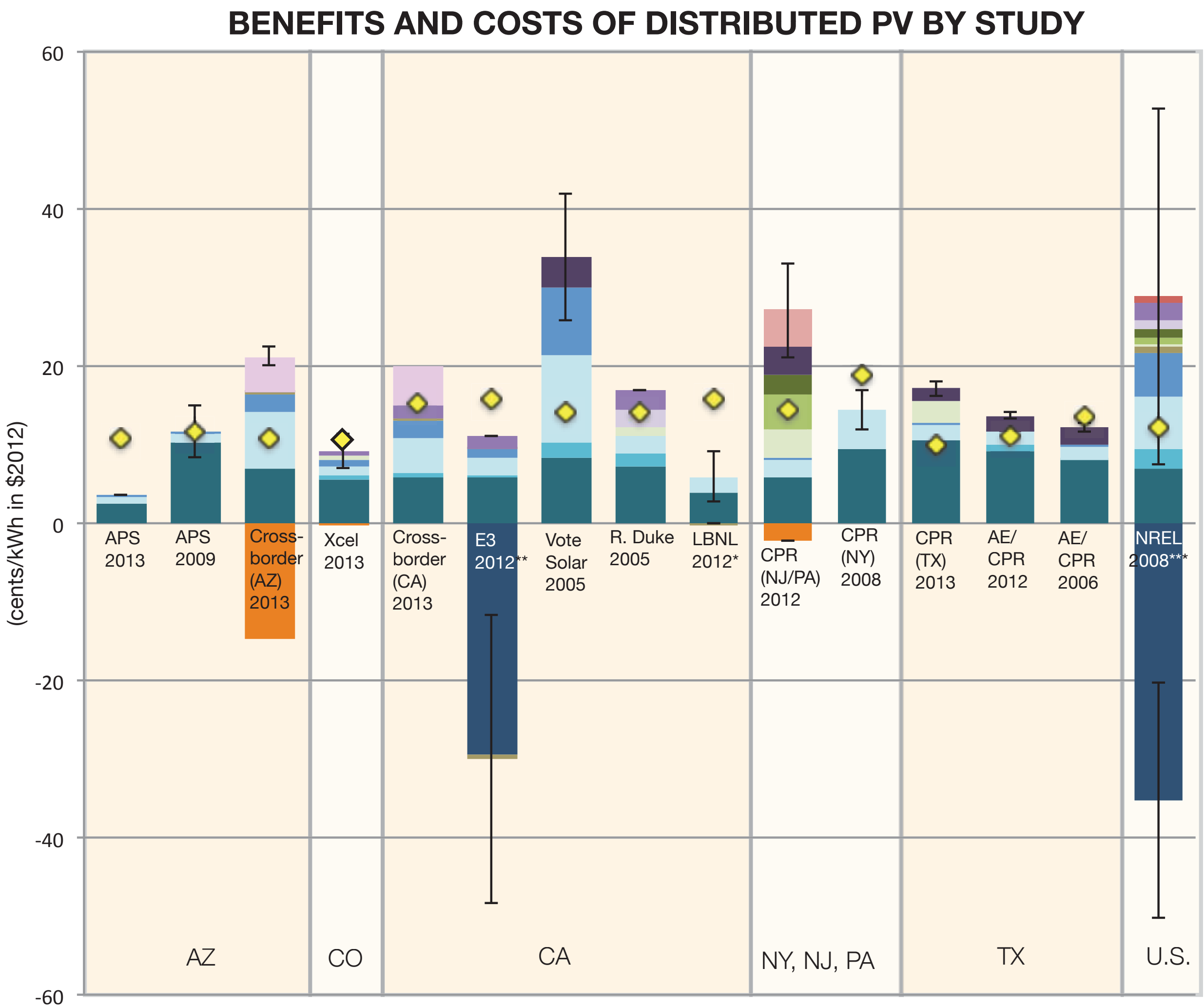
03

ANALYSIS OVERVIEW

THIS ANALYSIS INCLUDES 16 STUDIES, REFLECTING DIVERSE DPV PENETRATION LEVELS



SUMMARY OF DPV BENEFITS AND COSTS



Monetized

- Energy
- System Losses
- Gen Capacity
- T&D Capacity
- DPV Technology
- Grid Support Services
- Solar Penetration Cost

Inconsistently Monetized

- Financial: Fuel Price Hedge
- Financial: Mkt Price Response
- Security Risk
- Env. Carbon
- Env. Criteria Air Pollutants
- Env. Unspecified
- Env. Avoided RPS
- Social
- Customer Services

Average Local Retail Rate****
(in year of study, per EIA)

INSIGHTS

- No study com
benefits and c
acknowledge
cost and man
of benefit and

- There is a sig
across studie
in local conte
methodologic

- Because of th
results across
should be do
results must b
assumptions,

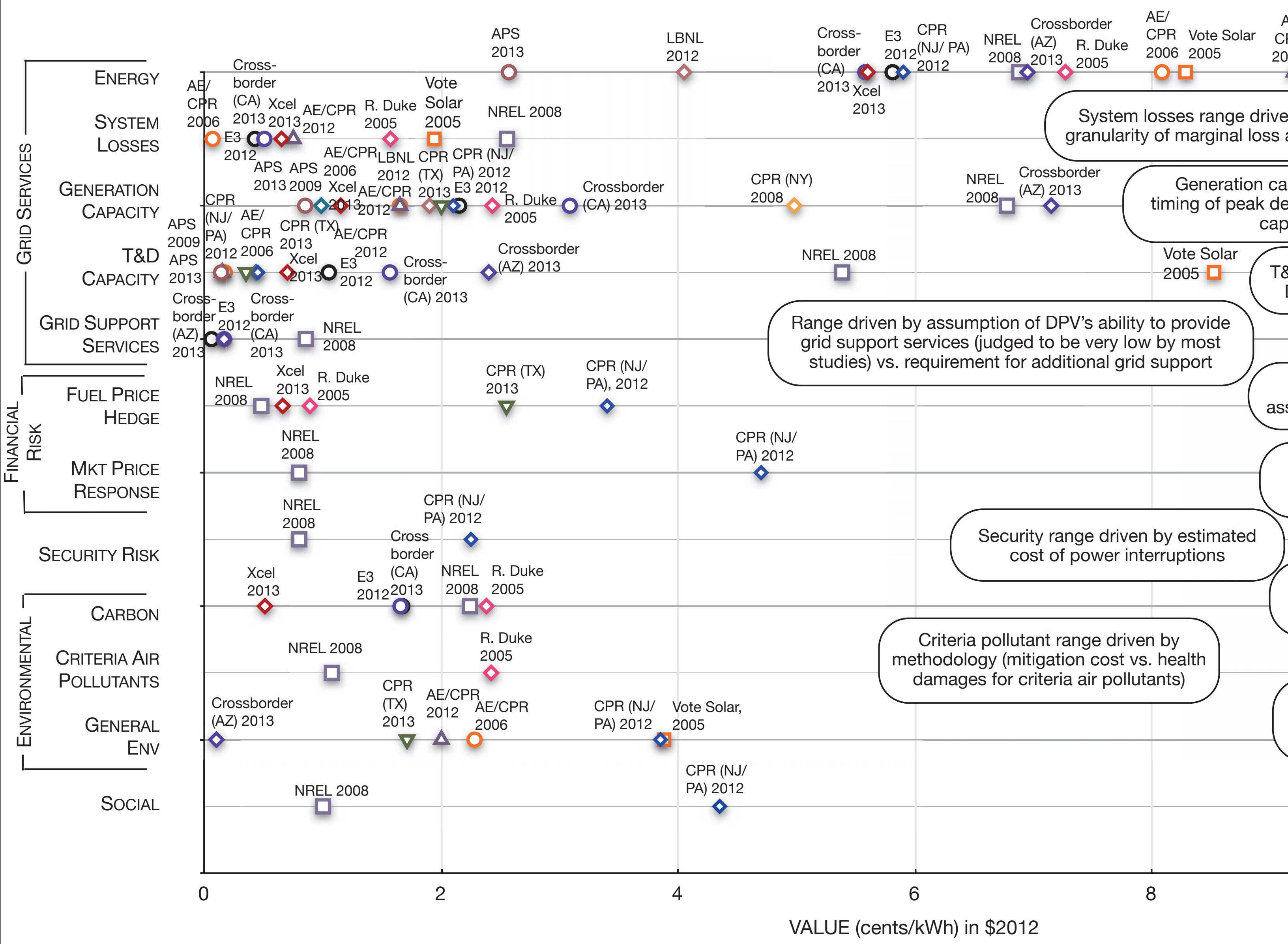
- While detailed
abound, there
approach to e
although there
capacity meth
less agreeme
estimating gri
unmonetized
security risk,

* The LBNL study only giv
** E3's DPV technology c
*** The NREL study is a r
Services, defined as the v
reflected in the NREL 200
report.
****Average retail rate i
compare the average ret
reflecting costs (i.e., net
designs (i.e., not average
Note: E3 2012 study not
itemize results. See page

BENEFIT ESTIMATES

THE RANGE IN BENEFIT ESTIMATES ACROSS STUDIES IS DRIVEN BY VARIATION IN SYSTEM CONTEX INPUT ASSUMPTIONS, AND METHODOLOGIES

PUBLISHED AVERAGE BENEFIT ESTIMATES*

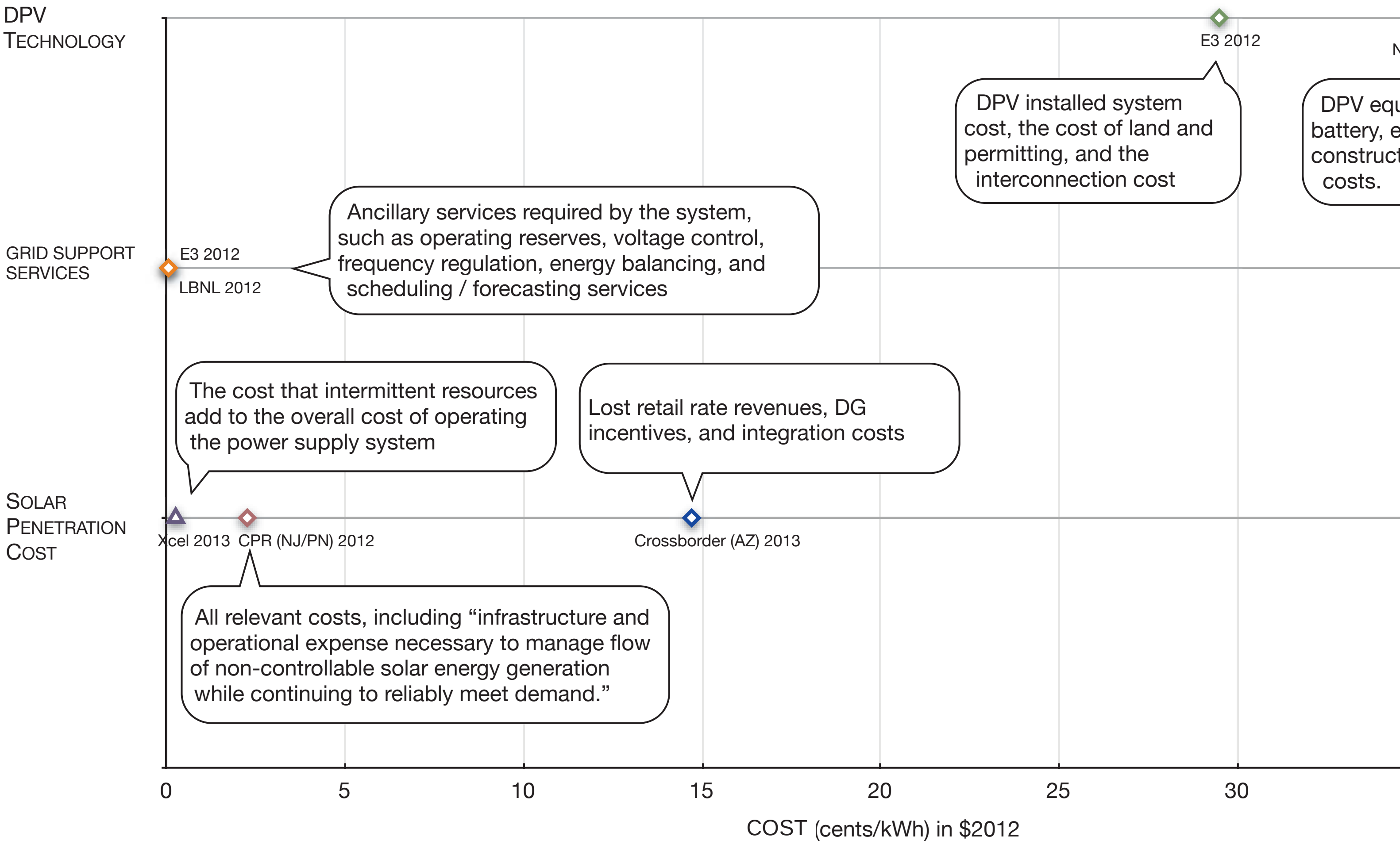


*For the full range of values observed see the individual methodology slides.

COST ESTIMATES

COSTS ASSOCIATED WITH INCREASED DPV DEPLOYMENT ARE NOT ADEQUATELY ASSESSED

PUBLISHED AVERAGE COST VALUES FOR REVIEWED SOURCES



Other studies (for example E3 2011) include costs, but results are not presented individually in the studies a
in the chart above. Costs generally include costs of program rebates or incentives paid by the utility, progra
costs, lost revenue to the utility, stranded assets, and costs and inefficiencies associated with throttling dow

ENERGY

VALUE OVERVIEW

Energy value is created when DPV generates energy (kWh) that displaces the need to produce energy from another resource. There are two components of energy value: the amount of energy that would have been generated equal to the DPV generation, and the additional energy that would have been generated but lost in delivery due to inherent inefficiencies in the transmission and distribution system. This second category of losses is sometimes reflected separately as part of the system losses category.

APPROACH OVERVIEW

There is broad agreement on the general approach to calculating energy value, although numerous differences in methodological details. Energy is frequently the most significant source of benefit.

- Energy value is the avoided cost of the marginal resource, typically assumed to be natural gas.
- Key assumptions generally include fuel price forecast, operating & maintenance costs, and heat rate, and depending on the study, can include system losses and a carbon price.

WHY AND HOW VALUES DIFFER

- **System Context:**
  - **Market structure** - Some Independent System Operators (ISOs) and states value capacity and energy separately, whereas some ISOs only have energy markets without capacity markets. ISOs with only energy markets may reflect capacity value in the energy price.
  - **Marginal resource characterization** - Studies in regions with ISOs may calculate the marginal price based on wholesale market prices, rather than on the cost of the marginal power plant; different resources may be on the margin in different regions or with different solar penetrations.
- **Input Assumptions:**
  - **Fuel price forecast** - Since natural gas is usually on the margin, most studies focus on natural gas prices. Studies most often base natural gas prices on the New York Mercantile Exchange (NYMEX) forward market and then extrapolate to some future date (varied approaches to this extrapolation), but some take a different approach to forecasting, for example, based on Energy Information Administration projections.
  - **Power plant efficiency** - The efficiency of the marginal resource significantly impacts energy value; studies show a wide range of assumed natural gas plant heat rates.
  - **Variable operating & maintenance costs** - While there is some difference in values assumed by studies, variable O&M costs are generally low.
  - **Carbon price** - Some studies include an estimated carbon price in energy value, others account for it separately, and others do not include it at all.
- **Methodologies:**
  - **Study window** - Some studies (for example, APS 2013) calculate energy value in a sample year, whereas others (for example, Crossborder (AZ) 2013) calculate energy value as a levelized cost over 20 years.
  - **Marginal resource characterization** - Studies take one of three general approaches: (1) DPV displaces energy from a gas plant, generally a combined cycle, (2) DPV displaces energy from one type of plant (generally a combined cycle) off-peak and a different type of plant (generally a combustion turbine) on-peak, (3) DPV displaces the resource on the margin during every hour of the year, based on a dispatch analysis.

ENERGY BEN
AS REPORTE

Xcel 201
APS, 2013
Crossboarder (AZ), 2013
CPR (TX), 2013
Crossborder (CA), 201
AE/CPR, 2012
CPR (NJ/PA), 2012
LBNL, 201
E3, 201
APS, 2009
NREL, 200
CPR (NY), 200
AE/CPR, 2006
Vote Solar, 200
R.Duke, 200

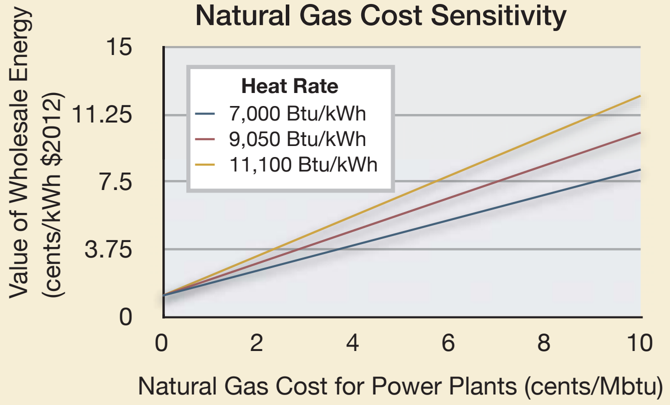
* = valu

Note: Benefits and costs
shown, study did not rep

ENERGY (CONT'D)

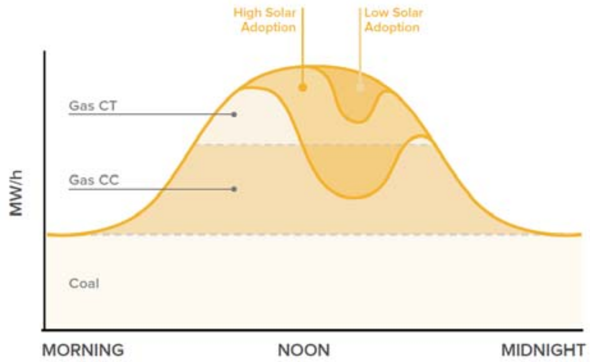
SENSITIVITIES TO KEY INPUT ASSUMPTIONS

Electric Generation:
Natural Gas Cost Sensitivity



INSIGHTS & IMPLICATIONS

- Accurately defining the marginal resource that DPV displaces requires approach as DPV penetration increases.



The resource on the dispat when the sol much is gene

More accurate, more complex

Marginal Resource Characterization	Pros
Single power plant assumed to be on the margin (typically gas CC)	Simple; often sufficiently accurate at low sola penetrations
Plant on the margin on-peak/plant on the margin off-peak	More accurately captures differences in energy value reflected in merit-order dispatc
Hourly dispatch or market assessment to determine marginal resource in every hour	Most accurate, especially with increasing penetration

- Taking a more granular approach to determining energy value also req characterization of DPV's generation profile. It's also critical to use solar year(s), to accurately reflect weather drivers and therefore generation an

- In cases where DPV is displacing natural gas, the NYMEX natural gas basis for a natural gas price forecast, adjusted appropriately for delivery apparent from studies reviewed what the most effective method is for es which the NYMEX market ends.

LOOKING FORWARD

As renewable and distributed resource (not just DPV) penetration increas the underlying load shape differently, requiring more granular analysis to

SYSTEM LOSSES

VALUE OVERVIEW

System losses are a derivation of energy losses, the value of the additional energy generated by central plants that is lost due to inherent inefficiencies (electrical resistance) in delivering energy to the customer via the transmission and distribution system. Since DPV generates energy at or near the customer, that additional energy is not lost. Energy losses act as a magnifier of value for capacity and environmental benefits, since avoided energy losses result in lower required capacity and lower emissions.

APPROACH OVERVIEW

Losses are generally recognized as a value, although there is significant variation around what type of losses are included and how they are assessed. Losses usually represent a small but not insignificant source of value, although some studies report comparatively high values.

- Energy lost in delivery magnifies the value of other benefits, including capacity and environment.
- Calculate loss factor(s) (amount of loss per unit of energy delivered) based on modeled or observed data.

WHY AND HOW VALUES DIFFER

- **System Context:**
  - **Congestion** - Because energy losses are proportional to the inverse of current squared, the higher the utilization of the transmission & distribution system, the greater the energy losses.
  - **Solar characterization**—The timing, quantity, and geographic location of DPV, and therefore its coincidence with delivery system utilization, impacts losses.
- **Input Assumptions:**
  - **Losses** - Some studies estimate losses by applying loss factors based on actual observation, others develop theoretical loss factors based on system modeling. Further, some utility systems have higher losses than others.
- **Methodologies:**
  - **Types of losses recognized** - Most studies recognize energy losses, some recognize capacity losses, and a few recognize environmental losses.
  - **Adder vs. stand-alone value** - There is no common approach to whether losses are represented as stand-alone values (for example, NREL 2008 and E3 2012) or as adders to energy, capacity, and environmental value (for example, Crossborder (AZ) 2013 and APS 2013), complicating comparison across studies.
  - **Temporal & geographic characterization** - Some studies apply an average loss factor to all energy generated by DPV, others apply peak/off-peak factors, and others conduct hourly analysis. Some studies also reflect geographically-varying losses.

SYSTEM LOSSES ESTIMATES AS R STUDIES

(

Xcel, 2013
[Increase in energy, capacity, emission and hedge values]

Crossboarder (CA), 2013
[Loss in energy from T&D across distance]

AE/CPR, 2012
[Increase in electricity, capacity, T&D, enviro values]

E3, 2012
[Loss in energy from T&D across distance]

NREL, 2008
[Increase in electricity, capacity, T&D, enviro values]

AE/CPR, 2006
[Increase in electricity, capacity, T&D, enviro values]

Vote Solar, 2005
[Increase in electricity, capacity, T&D, enviro values]

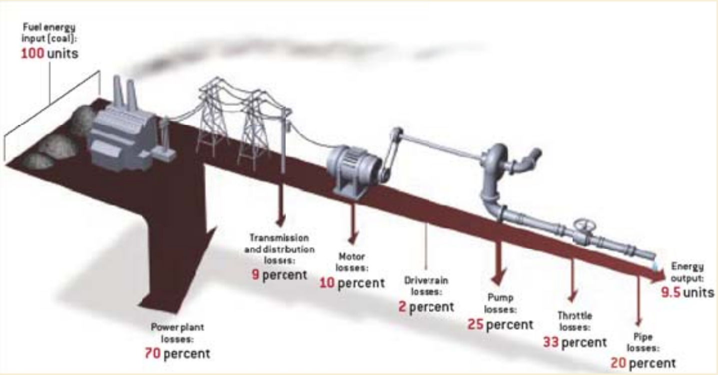
R. Duke, 2005
[Loss in energy from T&D across distance]

Note: Benefits and costs are refle
study did not represent costs.

SYSTEM LOSSES (CONT'D)

WHAT ARE SYSTEM LOSSES?

Some energy generated at a power plant is lost as it travels through the transmission and distribution system to the customer. As shown in the graphic below, more than 90% of primary energy input into a power plant is lost before it reaches the end use, or stated in reverse, for every one unit of energy saved or generated close to where it is needed, 10 units of primary energy are saved.



For the purposes of this discussion document, relevant losses are those driven by inherent inefficiencies (electrical resistance) in the transmission and distribution system, not those in the power plant or customer equipment. Energy losses are proportional to the square of current, and associated capacity benefit is proportional to the square of reduced load.

INSIGHTS & IMPLICATIONS

- All relevant system losses—energy, capacity, and environment—shoul
- Because losses are driven by the square of current, losses are significa Therefore, when calculating losses, it's critical to reflect marginal losses,
- Whether or not losses are ultimately represented as an adder to an un value, they are generally calculated separately. Studies should distinguis value for transparency and to drive consistency of methodology.

LOOKING FORWARD

Losses will change over time as the loading on transmission and distribu combination of changing customer demand and DPV generation.

GENERATION CAPACITY

VALUE OVERVIEW

Generation capacity value is the amount of central generation capacity that can be deferred or avoided due to the installation of DPV. Key drivers of value include (1) DPV's effective capacity and (2) system capacity needs.

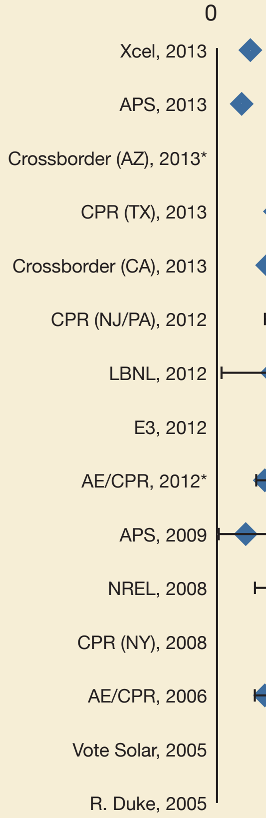
APPROACH OVERVIEW

Generation capacity value is the avoided cost of the marginal capacity resource, most frequently assumed to be a gas combustion turbine, and based on a calculation of DPV effective capacity, most commonly based on effective load carrying capability (ELCC).

WHY AND HOW VALUES DIFFER

- **System Context:**
  - **Load growth/generation capacity investment plan** - The ability to avoid or defer generation capacity depends on underlying load growth and how much additional capacity will be needed, at what time.
  - **Solar characteristics** - The timing, quantity, and geographic location of DPV, and therefore its coincidence with system peak, impacts DPV's effective capacity.
  - **Market structure** - Some ISOs and states value capacity and energy separately, whereas some ISOs only have energy markets but no capacity markets. ISOs with only energy markets may reflect capacity value as part of the energy price. For California, E3 2012 calculates capacity value based on "net capacity cost"—the annual fixed cost of the marginal unit minus the gross margins captured in the energy and ancillary service market.
- **Input Assumptions:**
  - **Marginal resource** - Most studies assume that a gas combustion turbine, or occasionally a gas combined cycle, is the generation capacity resource that could be deferred. What this resource is and its associated capital and fixed O&M costs are a primary determinant of capacity value.
- **Methodologies:**
  - **Formulation of DPV effective capacity** - There is broad agreement that DPV's effective capacity is most accurately determined using an ELCC approach, which measures the amount of additional load that can be met with the same level of reliability after adding DPV. There is some variation across studies in ELCC results, likely driven by a combination of underlying solar resource profile and ELCC calculation methodology. The approach to effective capacity is sometimes different when considering T&D capacity.
  - **Minimum DPV required to defer capacity** - Some studies (for example, Crossborder (AZ) 2013) credit every unit of effective DPV capacity with capacity value, whereas others (for example, APS 2009) require a certain minimum amount of solar be installed to defer an actual planned resource before capacity value is credited.
  - **Inclusion of losses** - Some studies include capacity losses as an adder to capacity value rather than as a stand-alone benefit.

GENERATION CA
COST ESTIMATES
REVIEWED STUD

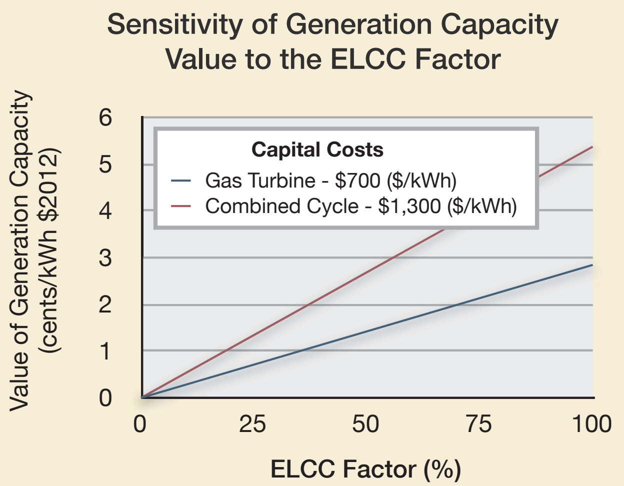


* = value includes generation

Note: Benefits and costs are refle
study did not represent costs.

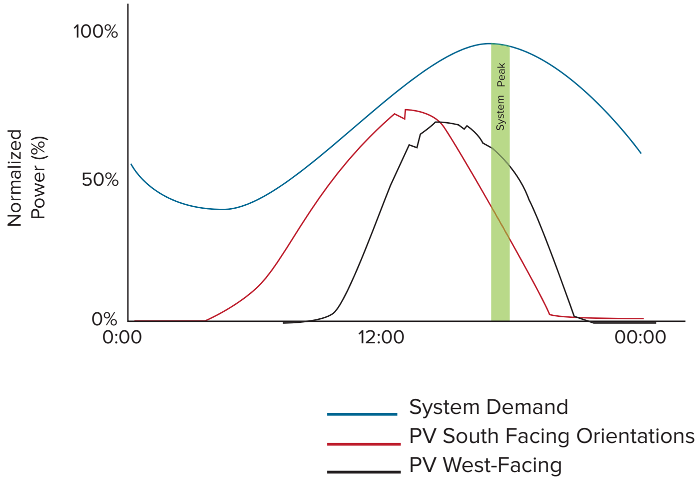
GENERATION CAPACITY (CONT'D)

SENSITIVITIES TO KEY INPUT ASSUMPTIONS



INSIGHTS & IMPLICATIONS

- Generation capacity value is highly dependent on the correlation of D
to accurately assess that correlation using an ELCC approach, as all st
results indicate possible different formulations of ELCC.



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- The value also depends on whether new capacity is needed on the sy
defers new capacity. It's important to assess what capacity would have
expected, or planned DPV.

- Generation capacity value is likely to change significantly as more DP
distributed resources of all kinds are added to the system. Some amou
costly resources in the capacity stack, but increasing amounts of DPV
resources. Similarly, the underlying load shape, and therefore even the
shift.

LOOKING FORWARD

Generation capacity is one of the values most likely to change, most qu
penetration. Key reasons for this are (1) increasing DPV penetration cou
peak to later in the day, when DPV generation is lower, and (2) increasin
expensive peaking resources, but once those resources are displaced,
lower. Beyond DPV, it's important to note that a shift towards more rene
concept of a daily or seasonal peak.

TRANSMISSION & DISTRIBUTION CAPACITY

VALUE OVERVIEW

The transmission and distribution (T&D) capacity value is a measure of the net change in T&D infrastructure as a result of the addition of DPV. Benefits occur when DPV is able to meet rising demand locally, relieving capacity constraints upstream and deferring or avoiding transmission or distribution upgrades. Costs are incurred when additional transmission or distribution investment are necessary to support the addition of DPV, which could occur when the amount of solar energy exceeds the demand in the local area and increases needed line capacity.

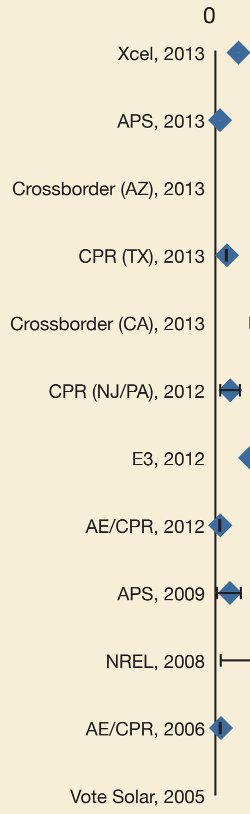
APPROACH OVERVIEW

The net value of deferring or avoiding T&D investments is driven by rate of load growth, DPV configuration and energy production, peak coincidence and effective capacity. Given the site specific nature of T&D, especially distribution, there can be significant range in the calculated value of DPV. Historically low penetrations of DPV has meant that studies have primarily focused on analyzing the ability of DPV to defer transmission or distribution upgrades and have not focused on potential costs, which would likely not arise until greater levels of penetration. Studies typically determine the T&D capacity value based on the capital costs of planned expansion projects in the region of interest. However, the granularity of analysis differs.

WHY AND HOW VALUES DIFFER

- **System Context:**
  - **Locational characteristics -** Transmission and distribution infrastructure projects are inherently site-specific and their age, service life, and use can vary significantly. Thus, the need, size and cost of upgrades, replacement or expansion correspondingly vary.
  - **Projected load growth/T&D capacity investment plan** - Expected rate of demand growth affects the need, scale and cost of T&D upgrades and the ability of DPV to defer or offset anticipated T&D expansions. The rate of growth of DPV would need to keep pace with the growth in demand, both by order of magnitude and speed.
  - **Solar characteristics** - The timing of energy production from DPV and its coincidence with system peaks (transmission) and local peaks (distribution) drive the ability of DPV to contribute as effective capacity that could defer or displace a transmission or distribution capacity upgrade.
  - **The length of time the investment is deferred** -The length of time that T&D can be deferred by the installation of DPV varies by the rate of load growth, the assumed effective capacity of the DPV, and DPV's correlation with peak. The cost of capital saved will increase with the length of deferment.
- **Input Assumptions:**
  - **T&D investment plan characteristics -** Depending upon data available and depth of analysis, studies vary by the level of granularity in which T&D investment plans were assessed–project by project or broader generalizations across service territories.
- **Methodologies:**
  - **Accrual of capacity value to DPV** - One of the most significant methodological differences is whether DPV has incremental T&D capacity value in the face of "lumpy" T&D investments (see implications and insights).
  - **Losses -** Some studies include the magnified benefit of deferred T&D capacity due to avoided losses within the calculation of T&D value, while others itemize line losses separately.

T&D CAPACITY ESTIMATES AS I STUDIES

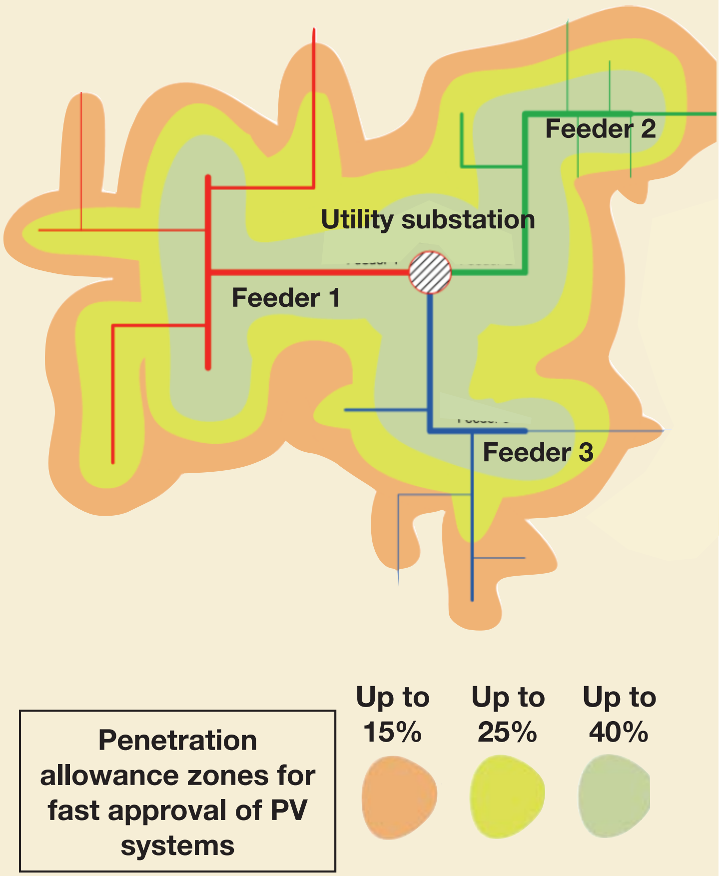


* = value includes T&

Note: Benefits and costs are ref
study did not represent costs.

TRANSMISSION & DISTRIBUTION CAPACITY (CONT'D)

LOCATIONAL CONSIDERATIONS AT THE DISTRIBUTION LEVEL



Adapted from Coddington, M. et al, *Updating Interconnection Screens for PV System Integration*

INSIGHTS & IMPLICATIONS

- Strategically targeted DPV deployment can relieve T&D capacity constra to demand and potentially deferring capacity investments, but dispersed to provide less benefit. Thus, the ability to access DPV's T&D deferral va distribution planning that incorporates distributed energy resources, suc

- The values of T&D are often grouped together, but they are unique wher costs and benefits that result from DPV.
  - While the ability to defer or avoid transmission is still locational dep distribution. Transmission aggregates disparate distribution areas a DPV at the distribution level typically require less granular data and
  - The distribution system requires more geographically specific data characteristics such as local hourly PV production and correlation w

- There are significantly differing approaches on the ability of DPV to accr avoidance value that require resolution:
  - How should DPV's capacity deferral value be estimated in the face While APS 2009 and APS 2013 posit that a minimum amount of so capacity before credit is warranted, Crossborder (AZ) 2013 credits with capacity value.
  - What standard should be applied to estimate PV's ability to defer a expansion project? While most studies use ELCC to determine effe APS 2013 use the level at which there is a 90% confidence of that

LOOKING FORWARD

Any distributed resources, not just DPV, that can be installed near the end user congestion along, the T&D network could potentially provide T&D value. This in energy to be used more efficiently or at different times, reducing the quantity of the T&D network (especially during peak hours).

GRID SUPPORT SERVICES

VALUE OVERVIEW

Grid support services, also commonly referred to as ancillary services (AS) in wholesale energy markets, are required to enable the reliable operation of interconnected electric grid systems, including operating reserves, reactive supply and voltage control; frequency regulation; energy imbalance; and scheduling.

APPROACH OVERVIEW

There is significant variation across studies on the impact DPV will have on the addition or reduction in the need for grid support services and the associated cost or benefit. Most studies focus on the cost DPV could incur in requiring additional grid support services, while a minority evaluate the value DPV could provide by reducing load and required reserves or the AS that DPV could provide when coupled with other technologies. While methodologies are inconsistent, the approaches generally focus on methods for calculating changes in necessary operating reserves, and less precision or rules of thumb are applied to the remainder of AS, such as voltage regulation. Operating reserves are typically estimated by determining the reliable capacity for which DPV can be counted on to provide capacity when demanded over the year.

WHY AND HOW VALUES DIFFER

- **System Context:**
  - **Reliability standards and market rules** - The standards and rules for reliability that govern the requirements for grid support services and reserve margins differ. These standards directly impact the potential net value of adding DPV to the system.
  - **Availability of ancillary services market** - Where wholesale electricity markets exist, the estimated value is correlated to the market prices of AS.
  - **Solar characteristics** - The timing of energy production from DPV and it's coincidence with system peaks differs locationally.
  - **Penetration of DPV** - As PV penetrations increase, the value of its reliable capacity decreases and, under standard reliability planning approaches, would increase the amount of system reserves necessary to maintain reliable operations.
  - **System generation mix** - The performance characteristics of the existing generation mix, including the generators ability to respond quickly by increasing or decreasing production, can significantly change the supply value of ancillary services and the value.
- **Methodologies:**
  - **Effective capacity of DPV** - The degree that DPV can be depended on to provide capacity when demanded has a direct effect on the amount of operating reserves that the rest of the system must supply. The higher the "effective capacity," the less operating reserves necessary.
  - **Correlating reduced load with reduced ancillary service needs** - Crossborder (AZ) 2013 calculated a net benefit of DPV based on 1) load reduction & reduced operating reserve requirements; 2) peak demand reduction and utility capacity requirements.
  - **Potential of DPV to provide grid support with technology coupling** - While the primary focus across studies was the impact DPV would have on the need for additional AS, NREL 2008 & AE/CPR 2006 both noted that DPV could provide voltage regulation with smart inverters were installed.

GRID SUPPORT S
COST ESTIMATES
REVIEWED STUDI

-

Crossborder (AZ) 2013
[Decreased operating & capacity reserve requirement]

Crossborder (CA) 2013
[Based on CAISO 2011 Market Values

LBNL 2012
[Market value of non-spinning reserves, spinning reserves, and regulation]

E3 2012
[1% of avoided energy value]

NREL 2008
[Meta-analysis]

APS 2009

Note: Benefits and costs are r
shown, study did not represen

GRID SUPPORT SERVICES (CONT'D)

Grid Support Services	The potential for DPV to provide grid support services (with technology modifications)
REACTIVE SUPPLY AND VOLTAGE CONTROL	**(+/-)** PV with an advanced inverter can inject/consume VARs, adjusting to control voltage
FREQUENCY REGULATION	**(+/-)** Advanced inverters can adjust output frequency; standard inverters may
ENERGY IMBALANCE	**(+/-)** If PV output < expected, imbalance service is required. Advanced inverters could adjust output to provide imbalance
OPERATING RESERVES	**(+/-)** Additional variability and uncertainty from large penetrations of DPV may introduce operations forecast error and increase the need for certain types of reserves; however, DPV may also reduce the amount of load served by central generation, thus, reducing needed reserves.
SCHEDULING / FORECASTING	**(-)** The variability of the solar resource requires additional forecasting to reduce uncertainty

INSIGHTS & IMPLICATIONS

- As with large scale renewable integration, there is still contro change in "ancillary services due to variable generation and how to allocate those costs between specific generators or
- Areas with wholesale AS markets enable easier quantificatio without markets have less standard methodologies for quan
- One of the most significant differences in reviewed method necessary amount of operating reserves, as specified by rec DPV's capacity value (as determined by ELCC, for example) and Vote Solar 2005 note that the addition of DPV reduces l thus allowing utilities to reduce procured reserves. Additiona whether the required level of reserves should be adjusted in
- Studies varied in their assessments of grid support services would contribute significantly to spinning or operating reserv reserves could be affected at high penetration levels.

LOOKING FORWARD

Increasing levels of distributed energy resources and variable renew both the need for grid support services as well as the types of asse them. The ability of DPV to provide grid support requires technolog as advanced inverters or storage, which incur additional costs. How proposition will increase as technology costs decrease and the opp provide these services increase with penetration.

FINANCIAL: FUEL PRICE HEDGE

VALUE OVERVIEW

DPV produces roughly constant-cost power compared to fossil fuel generation, which is tied to potentially volatile fuel prices. DPV can provide a "hedge" against price volatility, reducing risk exposure to utilities and customers.

APPROACH OVERVIEW

More than half the studies reviewed acknowledge DPV's fuel price hedge benefit, although fewer quantify it and those that do take different, although conceptually similar, approaches.

- In future years when natural gas futures market prices are available, using those NYMEX prices to develop a natural gas price forecast should include the value of volatility.
- In future years beyond when natural gas futures market prices are available, estimate natural gas price and volatility value separately. Differing approaches include:
    - Escalating NYMEX prices at a constant rate, under the assumption that doing so would continue to reflect hedge value (Crossborder (AZ) 2013); or
    - Estimating volatility hedge value separately as the value or an option/swap, or as the actual price adder the utility is incurring now to hedge gas prices (CPR (NJ/PA 2012), NREL 2008).

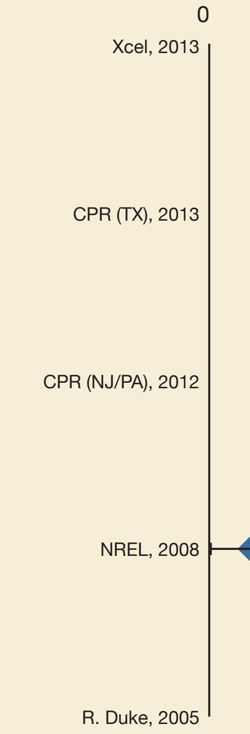
WHY AND HOW VALUES DIFFER

- **System Context:**
    - **Marginal resource characterization** - What resource is on the margin, and therefore how much fuel is displaced varies.
    - **Exposure to fuel price volatility** - Most utilities already hedge some portion of their natural gas purchases for some period of time in the future.
- **Methodologies:**
    - **Approach to estimating value** - While most studies agree that NYMEX futures prices are an adequate reflection of volatility, there is no largely agreed upon approach to estimating volatility beyond when those prices are available.

INSIGHTS & IMPLICATIONS

- NYMEX futures market prices are an adequate reflection of volatility in the years in which it operates.
- Beyond that, volatility should be estimated, although there is no obvious best practice. Further work is required to develop an approach that accurately measures hedge value.

FUEL PRICE HED
COST ESTIMATE
REVIEWED STUD



Note: Benefits and costs are refle
study did not represent costs.

FINANCIAL: MARKET PRICE RESPONSE

VALUE OVERVIEW

The addition of DPV, especially at higher penetrations, can affect the market price of electricity in a particular market or service territory. These market price effects span energy and capacity values in the short term and long term, all of which are interrelated. Benefits can occur as DPV provides electricity close to demand, reducing the demand for centrally-supplied electricity and the fuel powering those generators, thereby lowering electricity prices and potentially fuel commodity prices. A related benefit is derived from the effect of DPV's contribution at higher penetrations to reshaping the load profile that central generators need to meet. Depending upon the correlation of DPV production and load, the peak demand could be reduced and the marginal generator could be more efficient and less costly, reducing total electricity cost. However, these benefits could potentially be reduced in the longer term as energy prices decline, which could result in higher demand. Additionally, depressed prices in the energy market could have a feedback effect by raising capacity prices.

APPROACH OVERVIEW

While several studies evaluate a market price response of DPV, distinct approaches were employed by E3 2012, CPR (NJ/PN) 2012, and NREL 2008.

WHY AND HOW VALUES DIFFER

- **Methodologies:**
  - **Considering market price effects of DPV in the context of other renewable technologies** - E3 2012 incorporated market price effect in its high penetration case by adjusting downward the marginal value of energy that DPV would displace. However, for the purposes of the study, E3 2012 did not add this as a benefit to the avoided cost because they "assume the market price effect would also occur with alternative approaches to meeting [CA's] RPS."
  - **Incorporating capacity effects** -
    - E3 2012 represented a potential feedback effect between the energy and capacity by assuming an energy market calibration factor. That is, it assumes that, in the long run, the CCGT's energy market revenues plus the capacity payment equal the fixed and variable costs of the CCGT. Therefore, a CCGT would collect more revenue through the capacity and energy markets than is needed to cover its costs, and a decrease in energy costs would result in a relative increase in capacity costs.
    - CPR (NJ/PA) 2012 incorporates market price effect "by reducing demand during the high priced hours [resulting in] a cost savings realized by all consumers." They note "that further investigation of the methods may be warranted in light of two arguments...that the methodology does address induced increase in demand due to price reductions, and that it only addresses short-run effects (ignoring the impact on capacity markets)."

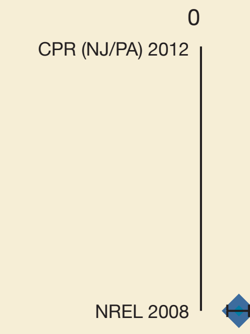
INSIGHTS & IMPLICATIONS

- The market price reduction value only assesses the initial market reaction of reduced price, not subsequent market dynamics (e.g. increased demand in response to price reductions, or the impact on the capacity market), which has to be studied and considered, especially in light of higher penetrations of DPV.

LOOKING FORWARD

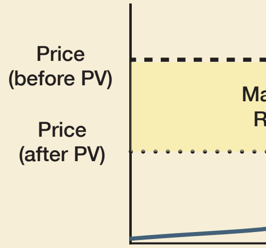
Technologies powered by risk-free fuel sources (such as wind) and technologies that increase the efficiency of energy use and decrease consumption would also have similar effects.

MARKET PRICE AND COST ESTI BY REVIEWED S



Note: Benefits and costs are refl study did not represent costs. A this study did not provide an

MARKET PRICE V



Source: CPR (NJ/PA) 2012

SECURITY: RELIABILITY AND RESILIENCY

VALUE OVERVIEW

The grid security value that DPV could provide is attributable to three primary factors, the last of which would require coupling DPV with other technologies to achieve the benefit:

1) The potential to reduce outages by reducing congestion along the T&D network. Power outages and rolling blackouts are more likely when demand is high and the T&D system is stressed.
2) The ability to reduce large-scale outages by increasing the diversity of the electricity system's generation portfolio with smaller generators that are geographically dispersed.
3) The benefit to customers to provide back-up power sources available during outages through the combination of PV, control technologies, inverters and storage.

APPROACH OVERVIEW

While there is general agreement across studies that integrating DPV near the point of use will decrease stress on the broader T&D system, most studies do not calculate a benefit due to the difficulty of quantification. CPR 2012 and 2011 did represent the value as the value of avoided outages based on the total cost of power outages to the U.S. each year, and the perceived ability of DPV to decrease the incidence of outages.

INSIGHTS & IMPLICATIONS

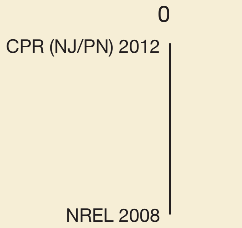
- The value of increased reliability is significant, but there is a need to quantify and demonstrate how much value can be provided by DPV. Rules-of-thumb assumptions and calculations for security impacts require significant analysis and review.

- Opportunities to leverage combinations of distributed technologies to increase customer reliability are starting to be tested. The value of DPV in increasing suppling power during outages can only be realized if DPV is coupled with storage and equipped with the capability to island itself from the grid, which come at additional capital cost.

LOOKING FORWARD

Any distributed resources that can be installed near the end user to reduce use of, and congestion along, the T&D network could potentially reduce transmission stress. This includes technologies that allow energy to be used more efficiently or at different times, reducing the quantity of electricity traveling through the T&D network (especially during peak hours). Any distributed technologies with the capability to be islanded from the grid could also play a role.

RELIABILITY AN AND COST ESTI BY REVIEWED S



Note: Benefits and costs are ref study did not represent costs.

Disruption (c

Sector
Residentia
Commercia
Industrial

*Disruption value is a measure events based on the increased increasing electricity consump

ENVIRONMENT: CARBON DIOXIDE

VALUE OVERVIEW

The benefits of reducing carbon emissions include (1) reducing future compliance costs, carbon taxes, or other fees, and (2) mitigating the heath and ecosystem damages potentially caused by climate change.

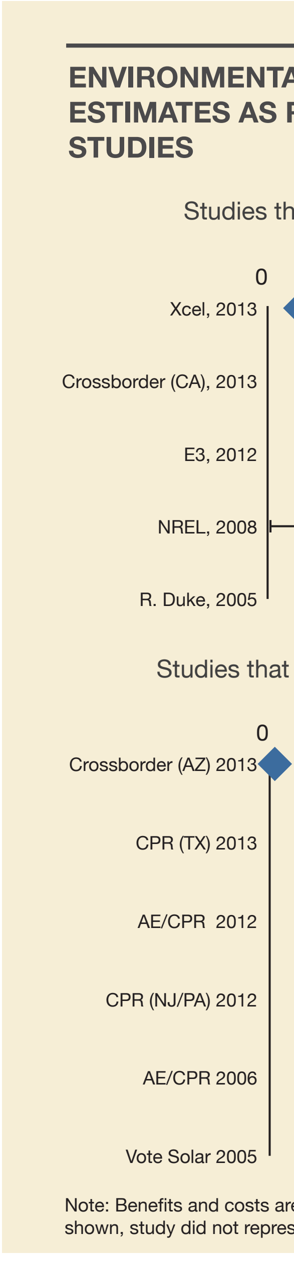
APPROACH OVERVIEW

By and large, studies that addressed carbon focused on the compliance costs or fees associated with future carbon emissions, and conclude that carbon reduction can increase DPV's value by more than two cents per kilowatt-hour, depending heavily on the price placed on carbon. While there is some agreement that carbon reduction provides value and on the general formulation of carbon value, there are widely varying assumptions, and not all studies include carbon value.

Carbon reduction benefit is the amount of carbon displaced times the price of reducing a ton of carbon. The amount of carbon displaced is directly linked to the amount of energy displaced, when it is displaced, and the carbon intensity of the resource being displaced.

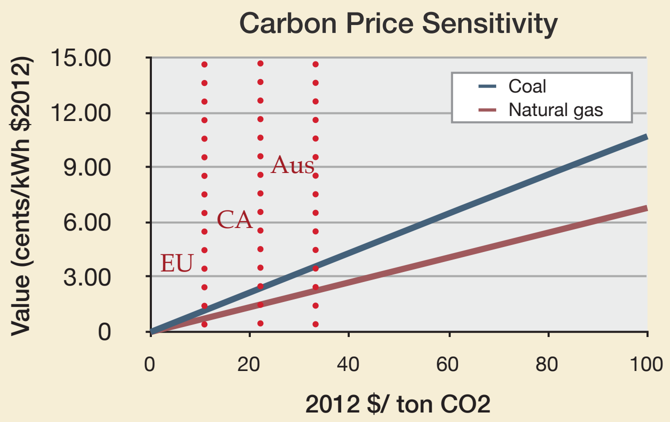
WHY AND HOW VALUES DIFFER

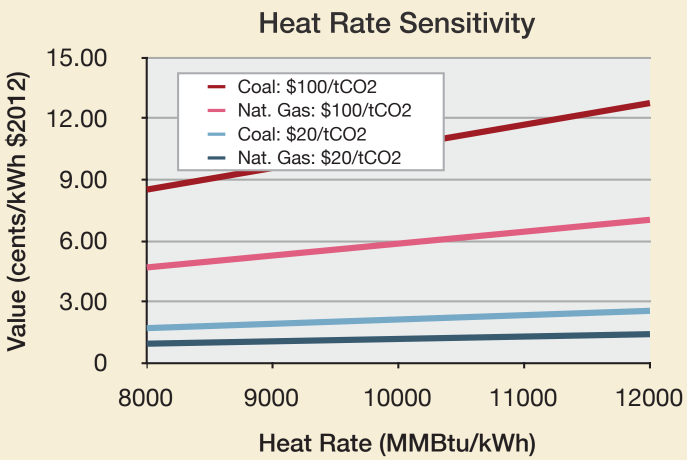
- **System Context:**
  - **Marginal resource characterization** - Different resources may be on the margin in different regions or with different solar penetrations. Carbon reduction is significantly different if energy is displaced from coal, gas combined cycles, or gas combustion turbines.
- **Input Assumptions:**
  - **Value of carbon reduction** - Studies have widely varying assumptions about the price or carbon. Some studies base price on reported prices in European markets, others on forecasts based on policy expectations, others on a combination. The increased uncertainty around U.S. Federal carbon legislation has made price estimates more difficult.
  - **Heat rates of marginal resources** - The assumed efficiency of the marginal power plant is directly correlated to amount of carbon displaced by DPV.
- **Methodologies:**
  - **Adder vs. stand-alone value** - There is no common approach to whether carbon is represented as a stand-alone value (for example, NREL 2008 and E3 2012) or as an adder to energy value (for example, APS 2013).
  - **Marginal resource characterization** - Just as with energy (which is directly linked to carbon reduction), studies take one of three general approaches: (1) DPV displaces energy from a gas plant, generally a combined cycle, (2) DPV displaces energy from one type of plant (generally a combined cycle) off-peak and a different type of plant (generally a combustion turbine) on-peak, (3) DPV displaces whatever resource is on the margin during every hour of the year, based on a dispatch analysis.



ENVIRONMENT: CARBON DIOXIDE
(CONT'D)

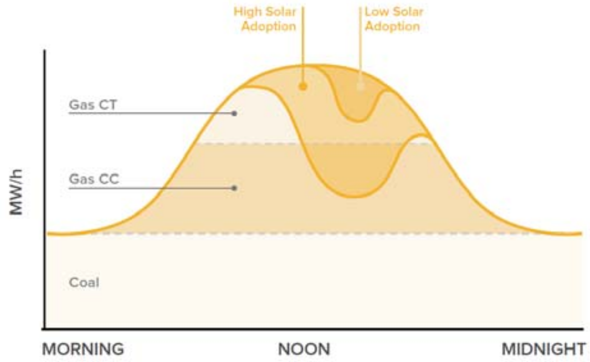
SENSITIVITY TO KEY INPUT ASSUMPTIONS





INSIGHTS & IMPLICATIONS

- Just as with energy value, carbon value depends heavily on what the r displaced. The same determination of the marginal resource should be u carbon values.



The amount c depends on t resources, wh and how muc

- While there is little agreement on what the $/ton price of carbon is or s

LOOKING FORWARD

While there has been no federal action on climate over the last few years about potential future prices, many states and utilities continue to value benefit. There appears to be increasing likelihood that the U.S. Environm action to limit emissions from coal plants, potentially providing a more c

ENVIRONMENT: OTHER FACTORS

In addition to carbon, DPV has several other environmental benefits (or potentially costs) that, while commonly acknowledged, are included in
here. That said, there is a significant body of thought for each outside the realm of DPV cost/benefit valuation, some of which is referenced bel

CRITERIA AIR POLLUTANTS

SUMMARY: Criteria air pollutants (NO_X, SO_2, and particulate matter) released from the burning of fossil fuels can produce both health and ecosystem damages. The economic cost of these pollutants is generally estimated as:

1. The compliance costs of reducing pollutant emissions from power plants, or the added compliance costs to further decrease emissions beyond some baseline standard; and/or

2. The estimated cost of damages, such as medical expenses for asthma patients or the value of mortality risk, which attempts to measure willingness to pay for a small reduction in risk of dying due to air pollution.

VALUE: Crossborder (AZ) 2013 estimated the value of criteria air pollutant reductions, based on APS's Integrated Resource Plan, as $0.365/MWh, and NREL 2008 as $0.2-14/MWh (2012$). CPR (NJ/PA) 2012 and AE/CPR 2012 also acknowledged criteria air pollutants, but estimate cost based on a combined environmental value.

RESOURCES:

Epstein, P., Buonocore, J., Eckerle, K. et al., *Full Cost Accounting for the Life Cycle of Coal*, 2011.

Muller, N., Mendelsohn, R., Nordhaus, W., *Environmental Accounting for Pollution in the US Economy.* American Economic Review 101, Aug. 2011. pp. 1649 - 1675.

National Research Council. *Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use,* 2010.

AVOIDED RENE PORTFOLIO STAN

SUMMARY: Investments in DPV can help the
Portfolio Standards (RPS) / Renewable Energy S

1. As DPV is installed and energy use from
decreases, the amount of renewable energy
to meet an RPS/RES decreases.

2. Depending on the RPS/RES requirement
translate into direct investments in renewab
they are able to receive credit, such as thro
(RECs).

VALUE: Crossborder (AZ) 2013 estimated the a
difference between the revenue requirements for
renewables scenario in APS's Integrated Resour
(CA) estimated the avoided RPS cost, based on
between RPS-eligible resources and the wholesa

RESOURCES:

Beach, R., McGuire, P., *The Benefits and Costs of So
Arizona Public Service.* Crossborder Energy May, 201

Beach, R., McGuire, P., *Evaluating the Benefits and C
Residential Customers in California.* Crossborder Ene

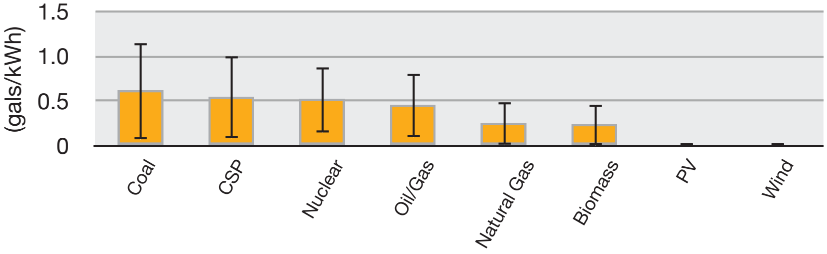
ENVIRONMENT: OTHER FACTORS

In addition to carbon, DPV has several other environmental benefits (or potentially costs) that, while commonly acknowledged, are included in
reviewed here. That said, there is a significant body of thought for each outside the realm of DPV cost/benefit valuation, some of which is refere

WATER

SUMMARY: Coal and natural gas power plants withdraw and consume water primarily for cooling. Approaches to valuing reduced water usage have focused on the cost or value of water in competing sectors, potentially including municipal, agricultural, and environmental/recreational uses.

WATER CONSUMPTION BY TECHNOLOGY



Source: Fthenakis

VALUE: The only study reviewed that explicitly values water reduction is Crossborder (AZ) 2013, which estimates a $1.084/MWh value based on APS's Integrated Resource Plan.

RESOURCES:

Tellinghulsen, S., *Every Drop Counts.* Western Resources Advocates, Jan. 2011.

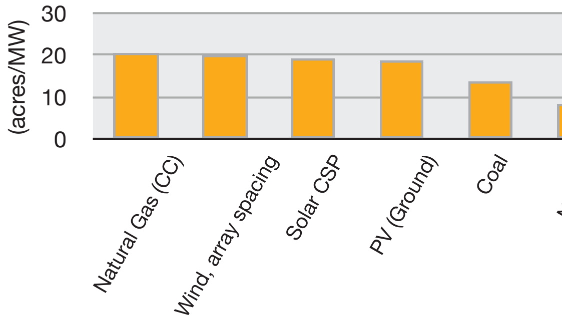
Fthenakis, V., Hyungl, C., *Life-cycle Use of Water in U.S. Electricity Generation.* Renewable and Sustainable Energy Review 14, Sept. 2010. pp.2039-2048.

LAND

SUMMARY: DPV can impact land in three ways:

1) Change in property value with the addition c
2) Land requirement for DPV installation, or
3) Ecosystem impacts of DPV installation.

LIFE-CYCLE LAND USE BY TEC



VALUE: None of the studies reviewed explicitly e

RESOURCES:

Goodrich et al. Residential, Commercial, and Utility Scale Pho
United States: Current Drivers and Cost-Reduction Opportun
14, 23—28

SOCIAL: ECONOMIC DEVELOPMENT

VALUE OVERVIEW

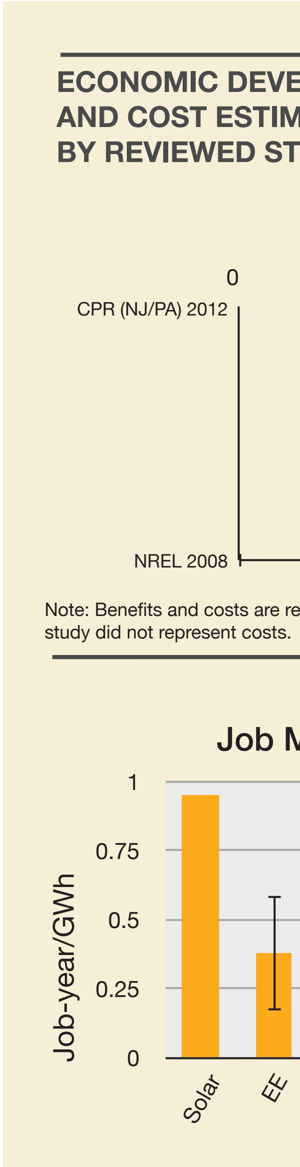
The assumed social value from DPV is based on any job and economic growth benefits that DPV brings to the economy, including jobs and higher tax revenue. The value of economic development depends on number of jobs created or displaced, as measured by a job multiplier, as well as the value of each job, as measured by average salary and/or tax revenue.

APPROACH OVERVIEW

Very few studies reviewed quantify employment and tax revenue value, although a number of them acknowledge the value. CPR (NJ/PN) 2012 calculated job impact based on enhanced tax revenues associated with the net job creation for solar vs conventional power resources. The 2011 study included increased tax revenue, decreased unemployment, and increased confidence for business development economic growth benefits, but only quantified the tax revenue benefit.

IMPLICATIONS AND INSIGHTS

- There is significant variability in the range of job multipliers.
- Many of the jobs created from PV, particularly those associated with installation, are local, so there can be value to society and local communities from growth in quantity and quality of jobs available. The locations where jobs are created are likely not the same as where jobs are lost. While there could be a net benefit to society, some regions could bear a net cost from the transition in the job market.
- While employment and tax revenues have not generally been quantified in studies reviewed, E3 2011 recommends an input-output modeling approach as an adequate representation of this value.



Sources: Wei, 2010

RESOURCES:

Wei, M., Patadia, S., and Kammen, D., Putting Renewables and Energy Efficiency to Work: How Many Jobs Can the Energy Industry Generate in the US? Energy Policy 38, 2010. pp. 919-931.

Brookings Institute, Sizing the Clean Economy: A National and Regional Green Jobs Assessment, 2011.

STUDY OVERVIEWS

04

SECTION STRUCTURE

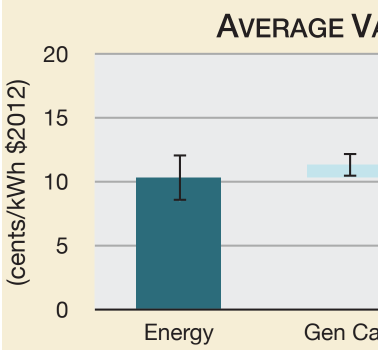
KEY COMPONENTS INCLUDED IN EACH STUDY OVERVIEW

STUDY CHARACTERISTICS	
STUDY OBJECTIVE	*A brief overview of the stated purpose of the study*
GEOGRAPHIC FOCUS	*Geographic region analyzed*
SYSTEM CONTEXT	*Relevant characteristics of the electricity system analyzed*
LEVEL OF SOLAR ANALYZED	*Solar penetrations analyzed, by energy or capacity*
STAKEHOLDER PERSPECTIVE	*Stakeholder perspectives analyzed (e.g., participant, ratepayer, society)*
GRANULARITY OF ANALYSIS	*Level of granularity reflected in the analysis as defined by:* ● *Solar characterization - How the solar generation profile is established (e.g., actual insolation data v. modeled, time correlated to load)* ● *Marginal resource/losses characterization - Whether the marginal resources and losses are calculated on a marginal hourly basis v. average* ● *Geographic granularity - Approach to estimating locationally-dependent benefits or costs (e.g., distribution feeders)*
TOOLS USED	*Key modeling tools used in the analysis*

Highlights

The Highlights section includes key observations about the study's approach, key drivers of results, and findings.

OVERVIEW OF VALUE CAT



The chart above de by category explore

The Overview of Va includes brief asses approach, relevant findings for each va

RW Beck for Arizona Public Service, 2009

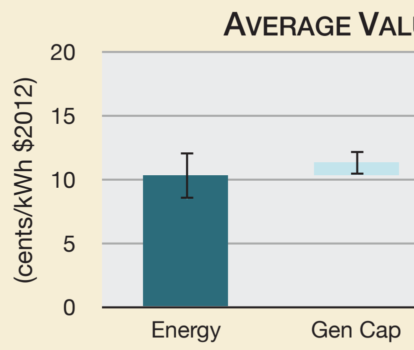
Distributed Renewable Energy Operating Impacts & Valuation Study

Study Characteristics	
STUDY OBJECTIVE	To determine the potential value of DPV for Arizona Public Service, and to understand the likely operating impacts.
GEOGRAPHIC FOCUS	Arizona Public Service territory
SYSTEM CONTEXT	Vertically integrated IOU, 15% RPS by 2025 with 30% distributed resource carveout
LEVEL OF SOLAR ANALYZED	0-16% by 2025 (by energy)
STAKEHOLDER PERSPECTIVE	Ratepayers
GRANULARITY OF ANALYSIS	• Solar characterization - Hourly TMY data, determined to be good approximation of calendar year data in a comparison • Marginal resource/losses characterization - Calculated based on hourly PROMOD simulation; theoretical hourly loss analysis; actual APS investment plan • Geographic granularity - Screening analysis of specific feeders; example constrained area and greenfield area analyzed
TOOLS USED	SAM 2.0; ABB's Feeder-All; EPRI's Distribution System Simulator; PROMOD

Highlights

- Value was measured incrementally in 2010, 2015, and 2025. The study approach combined system modeling, empirical testing, and information review, and represents one of the more technically rigorous approaches of reviewed studies.
- A key methodological assumption in the study is that generation, transmission, and distribution capacity value can only be given to DPV when it actually defers or avoids a planned investment. The implications are that a certain minimum amount of DPV must be installed in a certain time period (and in a certain location for distribution capacity) to create value.
- The study determines that total value decreases over time, primarily driven by decreasing capacity value. Increasing levels of DPV effectively pushes the system peak to later hours.
- The study acknowledged but did not quantify a number of other values including job creation, a more sustainable environment, carbon reduction, and increased worker productivity.

OVERVIEW OF VALUE CATEG



**this chart represents the present value of 20*

Energy: Energy provides the largest sourc
calculated based on a PROMOD hourly co
reduces fuel, purchased power requiremen
gas price forecast is based on NYMEX forw
APS's system.

Generation Capacity: There is little, but so
capacity value does not differ based on the
generation capacity investments are "lump
needed to displace it.

Capacity value includes benefits from redu
comparing DPV's dependable capacity (de
investment plan.

T&D Capacity: There is very little distribut
comes from targeting specific feeders. Sol
the system's peak load, DPV only has valu
overloaded condition, and DPV's dependa
increases. Distribution value includes capa
equipment sizing, and system performance

There is little, but some, transmission capa
on the geographic location of solar, but tra
significant amount of solar is needed to dis
capacity and potential detrimental impacts
(i.e., ancillary services).

T&D capacity value includes benefits from
combination of hourly system-wide and fe
is determined by comparing DPV's depend
plan. For T&D, as compared to generation,
level of solar output that will occur with 90
peak during summer months.

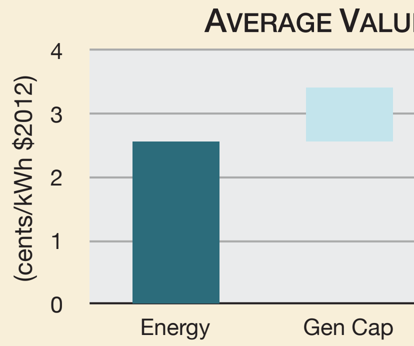
SAIC for Arizona Public Service, 2013
2013 Updated Solar PV Value Report

Study Characteristics	
STUDY OBJECTIVE	To update the valuation of future DPV systems in the Arizona Public Service (APS) territory installed after 2012.
GEOGRAPHIC FOCUS	Arizona Public Service territory
SYSTEM CONTEXT	Vertically integrated IOU, 15% RPS by 2025 with 30% distributed resource carve out, peak extends past sunset
LEVEL OF SOLAR ANALYZED	4.5-16% by 2025 (by energy)
STAKEHOLDER PERSPECTIVE	Ratepayers
GRANULARITY OF ANALYSIS	• Solar characterization - Hourly 30-year TMY data; coupled with production characteristics of actual installed systems • Marginal resource/losses characterization - Calculated based on hourly PROMOD simulation and APS investment plan as in 2009 study; average energy loss and system peak demand loss factors as recorded by APS • Geographic granularity - Screening analysis of existing feeders with >10% PV; based on that, determination of number of feeders where PV could reduce peak load from above 90% to below 90%
TOOLS USED	PVWatts; EPRI's DSS Distribution Feeder Model; PROMOD

Highlights

- Value was measured incrementally in 2015, 2020, and 2025.
- DPV provides less value than in APS's 2009 study, due to changing power market and system conditions. Energy generation and wholesale purchase costs have decreased due to lower natural gas prices. Expected CO_2 costs are significantly lower due to decreased likelihood of federal legislation. Load forecasts are lower, meaning reduced generation, distribution and transmission capacity requirements.
- The study notes the potential for increased value (primarily in T&D capacity) if DPV can be geographically targeted in sufficient quantities. However, it notes that actual deployment since the 2009 study does not show significant clustering or targeting.
- Like the 2009 study, capacity value is assumed to be based on DPV's ability to defer planned investments, rather than assuming every installed unit of DPV defers capacity.

OVERVIEW OF VALUE CATEG



**this chart represents the present value of 20*

Energy: Energy provides the largest sourc
calculated based on a PROMOD hourly c
reduces fuel, purchased power requireme
gas price forecast is based on NYMEX for
APS's system. Energy losses are included
2009 report, are based on a recorded ave

Generation Capacity: Generation capaci
dependable capacity during peak. Genera
simulations, and results in the deferral of c
energy losses are included as part of capa
based on a recorded peak demand loss. L
value is based on an ELCC calculation.

T&D Capacity: The study concludes that
that can defer capacity upgrades based o
determine measurable capacity savings. D
realized if distributed solar systems are ins
located on specific feeders to relieve cong
adoption has been geographically dispers
losses, capacity, extended service life, and

Transmission capacity value is highly depe
during peak. No transmission projects car
past the target years. As with the 2009 stu
purposes of T&D benefits is calculated ba
during peak summer hours. Benefits from

Crossborder Energy, 2013

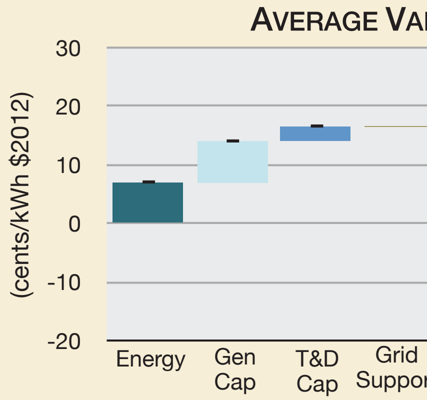
The Benefits and Costs of Solar Distributed Generation for Arizona Public Servic

Study Characteristics	
STUDY OBJECTIVE	To determine how demand-side solar will impact APS's ratepayers; a response to the APS 2013 study.
GEOGRAPHIC FOCUS	Arizona Public Service territory
SYSTEM CONTEXT	Vertically integrated IOU, 15% RPS by 2025
LEVEL OF SOLAR ANALYZED	DPV likely to be installed between 2013-2015; estimated here to be approximately 1.5%
STAKEHOLDER PERSPECTIVE	Ratepayers
GRANULARITY OF ANALYSIS	• Solar characterization - Not stated • Marginal resource/losses characterization - For energy, expected operating cost of a CT in peak months and CC in non-peak months; for capacity, fixed costs of a CT; marginal line loss factor from APS 2009 • Geographic granularity - Assumption that distribution investment can be deferred on 50% of feeders, based on APS 2009 conclusion that 50% of feeders show potential for reducing peak demand
TOOLS USED	Secondary analysis based on SAIC and APS detailed modeling

Highlights

- The benefits of DPV on the APS system exceed the cost by more than 50%. Key methodological differences between this study and the APS 2009 and 2013 studies include:
  - Determining value levelized over 20 years, as compared to incremental value in test years.
  - Crediting capacity value to every unit of solar DG installed, rather than requiring solar DG to be installed in "lumpy" increments.
  - Using ELCC to determine dependable capacity for generation, transmission, and distribution capacity values, as compared to using ELCC for generation capacity and a 90% confidence during peak summer hours for T&D capacity.
  - Focusing on solar installed over next few years years, rather than examining whether there is diminishing value with increasing penetration.
- The study notes that DPV must be considered in the context of efficiency and demand response—together they defer generation, transmission, and distribution capacity until 2017.

OVERVIEW OF VALUE CATEG



Energy: Avoided energy costs are the mos
term marginal resource is assumed to be a
combined cycle in off-peak months, and a
The natural gas price forecast is based on
study determines that it adequately captur
assumptions: $15/ton carbon adder, 12.1%

Generation Capacity: Generation capacit
capacity (based on DPV's near-term ELCC
of a gas combustion turbine. Every installe
based on the assumption that, when coupl
capacity would have otherwise been neede

T&D Capacity: T&D capacity value is calc
times APS's reported costs of T&D investm
installed unit is credited with T&D capacity
distribution feeders can see deferral benef
proactive approach to targeting DPV depl

Grid Support (Ancillary Services): DPV in
the need for ancillary services that would c
non-spinning, and capacity reserves.

Environmental: DPV effectively reduces lo
impacts that would otherwise be incurred.
pollutant emissions and lower water use (c
value).

Renewable Value: DPV helps APS meet it
lowering APS's compliance costs.

Solar Cost: Since the study takes a ratepa
retail rate revenues, incentive payments, a

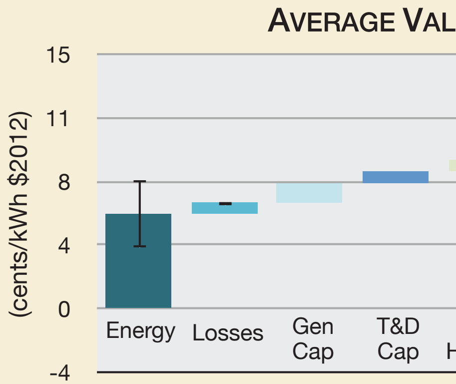
Xcel Energy for Public Service Company of Colorado, 2013
Costs and Benefits of Distributed Solar Generation on the Public Service Compan of Colorado System

Study Characteristics	
STUDY OBJECTIVE	To determine the costs and benefits of DPV on the Public Service Company of Colorado's electric power supply system at current penetration levels and projections for near-term penetration levels.
GEOGRAPHIC FOCUS	Public Service Company of Colorado's territory
SYSTEM CONTEXT	Vertically integrated IOU, 30% RPS by 2020 (includes DG standard)
LEVEL OF SOLAR ANALYZED	2012 DPV solar capacity: 59 MW; Est penetration in 2014: 140 MW installed by 2014
STAKEHOLDER PERSPECTIVE	System (excludes participant expenses (PV cost), solar program administration costs, or program incentive payments)
GRANULARITY OF ANALYSIS	• Solar characterization - Single TMY2 hourly generation profile weighted to represent entire 59 MW of DPV on PSCO's system used to calculate avoided energy costs & certain components of distribution system analysis; Historical meter data from 9 PV systems in 2009, 14 systems in 2010 (each >250 kW) used to estimate DPV capacity credit • Marginal resource/losses characterization - Calculated based on hourly PROMOD simulation; theoretical hourly loss analysis • Geographic granularity - Hourly feeder level data from small subset of feeders extrapolated to system
TOOLS USED	ProSym; NREL's TMY2 data sets using PV Watts

Highlights

- The study concludes that the most significant avoided cost from DPV (>90%) is from avoided energy costs.
- Energy value was calculated by comparing ProSym simulations with and without DPV, and the results were highly sensitive to assumed natural gas price forecasts. To estimate annual avoided energy costs, ProSym modeling used a single TMY2 generation profile (weighted by distribution of PV across PSCO's system), which was non-serially correlated with system load data.
- For the study, Xcel updated its ELCC calculations that are used to estimate capacity credit for DPV. In comparison to its previous 2009 ELCC study, the updated capacity credit for DPV across the four solar zones used is roughly 30% lower. The capacity credits range from 27%-32% for fixed installations and 40%-46% for tracking PV.

OVERVIEW OF VALUE CATEG



Energy: Costs are calculated on a marginal ba dispatch simulation using the TMY2 data set. O&M, and generation unit start costs. ProSym displace generation that is blend of an efficien efficient CT (10 MMBtu/MWh) through 2035. It a mix of gas-fired and coal-fired generation (be

System Losses: Avoided T&D lines losses we emissions, fuel hedge value and generation ca estimated using actual hourly feeder load data DPV generation, and using an estimated value losses were used to estimate savings from ene basis for generation capacity. Transmission lin weighted values, were used to calculate energ avoided generation capacity was based on los

Generation Capacity: Avoided generation ca of capacity until 2017, and after that (because economic carrying charge of a generic CT's ca generation capacity cost is credited to DPV ba load and solar generation patterns for 2009 an

T&D Capacity: DPV is assumed to defer distri years only if the existing feeder's peak load is feeder's peak load is decreased by ~10%.

Fuel Price Hedge Value: While the study note studies to estimate fuel price hedge value from explicitly stated how the fuel price hedge was

Carbon: Annual tons of CO_2 emissions avoide avoided cost case simulations. Change in mar changes in generation fleet (primarily retiremen

Solar Cost: Defined as "Integration Costs," or operating the Public Service power supply sys the actual net load differs from the day-ahead composed of electricity production costs level

ENERGY AND ENVIRONMENTAL ECONOMICS, INC. (E3), 2011
CALIFORNIA SOLAR INITIATIVE COST-EFFECTIVENESS EVALUATION

STUDY CHARACTERISTICS	
STUDY OBJECTIVE	"To perform a cost-effectiveness evaluation of the California Solar Initiative (CSI) in accordance with the CSI Program Evaluation Plan."
GEOGRAPHIC FOCUS	California
SYSTEM CONTEXT	Study: CSI program, retail net metering CA: 33% RPS, ISO market
LEVEL OF SOLAR ANALYZED	1,940 MW program goal (<1% of 2016 peak load)
STAKEHOLDER PERSPECTIVE	Participants (DPV customers), Ratepayers, Program Administrator, Total Resource, Society
GRANULARITY OF ANALYSIS	• Solar characterization - Hourly PV output profiles based on metered and simulated PV output data • Marginal resource/losses characterization - Energy: historical hourly day-ahead market price shapes (CAISO); Capacity: fixed cost of a new CT less net energy, AS revenues (see Overview box); Energy loss factors by TOU period, season; Capacity loss factors at peak periods • Geographic granularity - Major climate zones for each IOU; costs from utility rate case filings used as proxy for long-run marginal cost T&D investment avoided
TOOLS USED	E3 Avoided Cost Calculator (2011)

Highlights

- The study concludes that DPV is not expected to be cost-effective from a total resource or rate impact perspective during the study period, but that participant economics will not hinder CSI adoption goals. Program incentives support participant economics in the short-run, but DPV is expected to be cost-effective for many residential customers without program incentives by 2017. The study suggests that the value of non-economic benefits of DPV should be explored to determine if and how they provide value to California.

- The study focuses on seven benefits including energy, line losses, generation capacity, T&D capacity, emissions, ancillary services, and avoided RPS purchases. It focuses on costs including net energy metering bill credits, rebates/incentives, utility interconnection, costs of the DG system, net metering costs, and program administration.

- The study assesses hourly avoided costs in each of California's 16 climate zones to reflect varying costs in those zones, and calculates benefits and costs as 20-year levelized values. It uses E3's avoided cost model.

OVERVIEW OF VALUE CATEG

This study assesses overall cost-effective cost test, ratepayer impact measure, prog and societal cost) as defined in the Califor presents total rather than itemized results. here in a chart.

Energy: Hourly wholesale value of energy transaction. Natural gas price is based on long-run forecast of natural gas prices.

System Losses: Losses between the deli energy transaction. Losses scale with ene peak periods.

Generation Capacity: Value of avoiding r gas combustion turbine) to meet system p avoided due to decreased energy losses. capacity after the resource balance year. V resource balance year) because of CAISO

T&D Capacity: Value of deferring T&D ca

Grid Support Services (Ancillary Servic services market prices, scaled with the pr services included are regulation up, regula spinning reserves, and value is based on procurement of each AS.

Avoided RPS: Value is the incremental av resources to meet California's RPS.

Environmental: Value of CO_2 reduction, forecasts. Unpriced externalities (primarily kWh based on secondary sources.

Social: The study acknowledges that cus more energy efficiency, but does not atter acknowledges potential benefits associat suggests that an input-output model wou these benefits are not quantified in this st

Energy and Environmental Economics, Inc. (E3), 2012

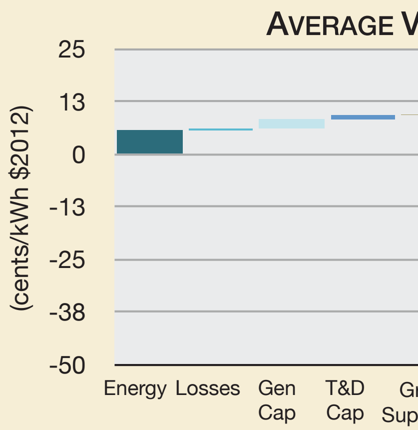
Technical Potential for Local Distributed Photovoltaics in California

Study Characteristics	
Study Objective	To estimate the technical potential of local DPV in California, and the associated costs and benefits.
Geographic Focus	California
System Context	California's 3 investor-owned utilities (IOU): PG&E, SDG&E, SCE
Level of Solar Analyzed	< 24% system peak load
Stakeholder Perspective	Total resource cost (TRC)
Granularity of Analysis	• Solar characterization - Simulated hourly PV output for each configuration (horizontal, fixed tilt, tracking) for each substation based on 2010 weather • Marginal resource/losses characterization - Energy: historical hourly day-ahead market price shapes (CAISO); Capacity: fixed cost of a new CT less net energy, AS revenues (see Overview box); Energy loss factors by TOU period, season; Capacity loss factors at peak periods • Geographic granularity - Compared hourly load at the individual substation level to potential PV generation at the same location at 1,800 substations
Tools Used	E3 Avoided Cost Calculator

Highlights

- Local DPV is defined as PV sized such that its output will be consumed by load on the feeder or substation where it is interconnected. Specifically, the generation cannot backflow from the distribution system onto the transmission system.
- The process for identifying sites included using GIS data to identify sites surrounding each of approximately 1,800 substations in PG&E, SDG&E and SCE. The study compared hourly load that the individual substation level to potential DPV generation at the same location.
- Cost of local distributed DPV increases significantly with Investment Tax Credit (ITC) expiration in 2017.
- When DPV is procured on a least net cost basis, opportunities may exist to locate in areas with high avoided costs. In 2012, a least net cost procurement approach results in net costs that are approximately $65 million lower assuming avoided transmission and distribution costs can be realized. These benefits carry through to 2016 for the most part, but disappear by 2020, when all potential has been realized regardless of cost.

Overview of Value Categ



Energy: Estimate of hourly wholesale va
the point of wholesale transaction and d
forwards that transition to annual averag
and operating costs of a new CCGT, less
ancillary service, and capacity markets. I
hourly day-ahead market price shapes fr

System Losses: Losses between the de
energy transaction. Losses scale with en
peak periods.

Generation Capacity: In the long-run (a
capacity value is based on the fixed cost
real-time energy and ancillary services m
based on a resource adequacy value.

T&D Capacity: Value is based on the "p
deferment value, incorporating investme

**Grid Support Services (Ancillary Servic
reserves, scaling with energy.

Carbon: Value of CO_2 emissions, based
a meta-analysis of forecasted carbon pri

Solar Cost -The installed system cost, t
interconnection cost

*E3's components of electricity avoided costs inclu
ancillary services, T&D capacity, environment.

Crossborder Energy for Vote Solar Initiative, 2013

Evaluating the Benefits and Costs of Net Energy Metering in California

Study Characteristics	
STUDY OBJECTIVE	"To explore recent claims from California's investor-owner utilities that the state's NEM policy causes substantial cost shifts between energy customers with Solar PV systems and non-solar customers, particularly in the residential market."
GEOGRAPHIC FOCUS	California
SYSTEM CONTEXT	33% RPS, retail net metering, increasing solar penetration, ISO market
LEVEL OF SOLAR ANALYZED	Up to 5% of peak (by capacity)
STAKEHOLDER PERSPECTIVE	Ratepayers
GRANULARITY OF ANALYSIS	• Solar characterization - Used PVWatts to produce hourly PV outputs at representative locations • Marginal resource/losses characterization - Based on E3 avoided cost model (Sept 2011), which determines hourly energy market values and capacity based on CT (since resource balance year not used in this study) • Geographic granularity - Major climate zones for each IOU; costs from utility rate case filings used as proxy for long-run marginal cost T&D investment avoided
TOOLS USED	E3 Avoided Cost Calculator (2011), PVWatts

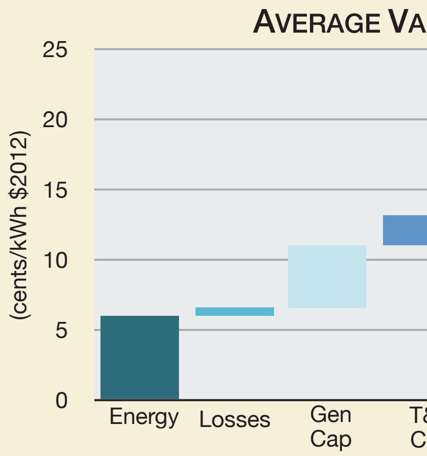
Highlights

- The study concludes that "on average over the residential markets of the state's three big IOUs, NEM does not impose costs on non-participating ratepayers, and instead creates a small net benefit." This conclusion is driven by "recent significant changes that the CPUC has adopted in IOUs' residential rate designs" plus "recognition that [DPV]...avoid other purchases or renewable power, resulting in a significant improvement in the economics of NEM compared to the CPUC's 2009 E3 NEM Study."

- The study focused on seven benefits: avoided energy, avoided generation capacity, reduced cost for ancillary services, lower line losses, reduced T&D investments, avoided RPS purchases, and avoided emissions. The study's analysis reflects costs to other customers (ratepayers) from "bill credits that the utility provides to solar customers as compensation for NEM exports, plus any incremental utility costs to meter and bill NEM customers." These costs are not quantified and levelized individually in the report, so they are not reflected in the chart to the right.

- The study bases its DPV value assessment on E3's avoided cost model and approach. It updates key assumptions including natural gas price forecast, greenhouse gas allowance prices, and ancillary services revenues, and excludes the resource balance year approach (the year in which avoided costs change from short-run to long-run). The study views the resource balance year as inconsistent with the modular, short lead-time nature of DPV. The study only considered the value of the exports to the grid under the utility's NEM program.

OVERVIEW OF VALUE CATEG



Energy: Wholesale value of energy adjust
wholesale transaction and the point of de
price forecast and greenhouse gas price f

System Losses: The loss in energy from
distance.

Generation Capacity: The cost of buildi
peak loads. Crossborder does not use E3
means that generation capacity value is b

T&D Capacity: The costs of expanding tr
meet peak loads.

Grid Support Services (Ancillary Servic
operations and reserves for electricity gri
ancillary services revenues.

Carbon: The cost of carbon dioxide emis
generating resource.

Avoided RPS: The avoided net cost of pr
RPS Portfolio that is a percentage of total
loads.

Vote Solar Initiative, 2005
Quantifying The Benefits Of Solar Power For California

Study Characteristics	
Study Objective	To provide a quantitative analysis of key benefits of solar energy for California.
Geographic Focus	California
System Context	California's 3 investor-owned utilities (IOU): PG&E, SDG&E, SCE
Level of Solar Analyzed	Unspecified
Stakeholder Perspective	Utility, ratepayer, participant, society
Granularity of Analysis	• Solar characterization - Assumed average solar PV ELCC to be 50% from range of 36%-70% derived from NREL study[1] • Marginal resource/losses characterization - Assumed natural gas generation plant on margin both for peak demand and non-peak periods • Geographic granularity - Not considered in this study
Tools Used	Spreadsheet analysis

Highlights

- The study concluded that the value of on-peak solar energy in 2005 ranged from $0.23 - 0.35 /kWh.

- The analysis looks at avoided costs under two alternative scenarios for the year 2005. The two scenarios vary the cost of developing new power plants and the price of natural gas.

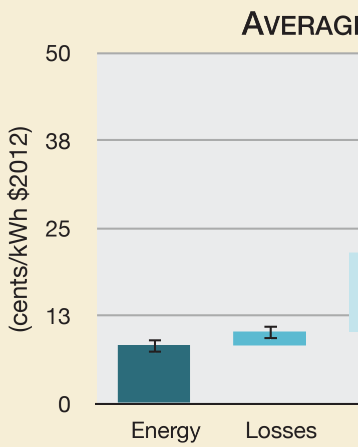
    - Scenario 1 assumed new peaking generation will be built by the electric utility at a cost of capital of 9.5% with cost recovery over a 20 year period; the price of natural gas is based on the 2005 summer market price (average gas price)

    - Scenario 2 assumed new peaking generation will be built by a merchant power plant developer at a cost of capital of 15% with cost recovery over a 10 year period; the price of natural gas is based on the average gas price in California for the period of May 2000 through June 2001 (high gas price – 24% higher)

- While numerous unquantifiable benefits were noted, five benefits were quantified:
    1) Deferral of investments in new peaking power capacity
    2) Avoided purchase of natural gas used to produce electricity
    3) Avoided emissions of CO_2 and NO_x that impact global climate and local air quality
    4) Reduction in transmission and distribution system power losses
    5) Deferral of transmission and distribution investments that would be needed to meet growing loads.

- The study assumed that, "in California, natural gas is the fuel used by power plants on the margin both for peak demand periods and non-peak periods. Therefore it is reasonable to assume the solar electric facilities will displace the burning of natural gas in all hours that they produce electricity."

Overview of Value C



Energy: Avoided fuel and variable
assumed heat rate of peaking pow
of consumables such as water and
kWh. For non-peak, average heat r
were used for each electric utility's
8740 MMBtu/kWh, SCE - 9690 MM

System Losses: Solar assumed to
summer peak and the summer sho
additional benefit derived from sola
at load.

Generation Capacity: Cost of ins
plant multiplied by DPV's ELCC an
costs per kilowatt hour by expecte

T&D Capacity: One study area wa
value of solar electricity in avoiding
need for T&D upgrades was assum
5% of the hours in a year. The 50%
value of avoided T&D upgrades.

Carbon: Assumed to be the avoid
marginal generator (natural gas). C

1 "Solar Resource-Utility Load-Matching As
Laboratory, 1994

RICHARD DUKE, ENERGY POLICY, 2005

ACCELERATING RESIDENTIAL PV EXPANSION: DEMAND ANALYSIS FOR COMPETITIVE ELECTRICITY

STUDY CHARACTERISTICS	
STUDY OBJECTIVE	To quantify the potential market for grid-connected, residential PV electricity integrated into new houses built in the US.
GEOGRAPHIC FOCUS	California and Illinois
SYSTEM CONTEXT	California: 33% RPS, mostly gas generation; Illinois: mostly coal generation
LEVEL OF SOLAR ANALYZED	not stated; assumed low
STAKEHOLDER PERSPECTIVE	System
GRANULARITY OF ANALYSIS	• Solar characterization - Single estimated insolation for two states analyzed • Marginal resource/losses characterization - For energy, marginal resource is a natural gas plant in California and a cola plant in Illinois. For capacity, marginal resource is a gas turbine in both states. Losses based on average and peak loss factors estimated in secondary sources. • Geographic granularity - Transmission and distribution system impacts not accounted for since they are site specific
TOOLS USED	High level, largely based on secondary analysis

Highlights

- Total value varies significantly between the two regions studied largely driven by what the off-peak marginal resource is (gas vs coal). Coal has significantly higher air pollution costs, although lower fuel costs.

- The study notes that true value varies dramatically with local conditions, so precise calculations at a high-level analysis level are impossible. As such, transmission and distribution impacts were acknowledged but not included.

OVERVIEW OF VALUE CATEG

AVERAGE VALU

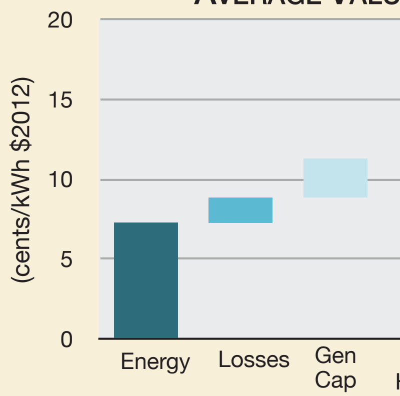


*Chart data only reflects California as

Energy: Energy value is based on the mar turbine) and off-peak (inefficient gas in Ca based on Energy Information Administrati

System Losses: Energy losses are assun that on-peak. Losses are only included as

Generation Capacity: Generation capaci marginal resource is always a gas combus an ELCC estimate from secondary source

Fuel Price Hedge Value: Hedge value is utilities of a fixed natural gas price for up hedge is assumed to be additive since EIA futures market.

Criteria Air Pollutants: Criteria air polluta costs of health impacts, estimated by sec

Carbon: Carbon value is the price of carb projections) times the amount of carbon c

Lawrence Berkeley National Lab, 2012

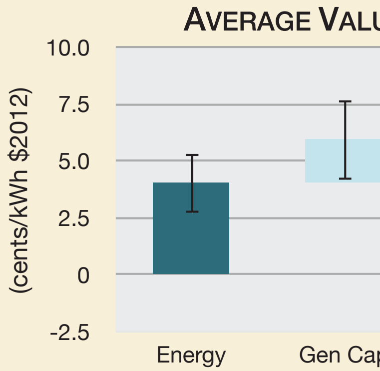
Changes in the Economic Value of Variable Generation at High Penetration Levels: Pilot Case Study of California

Study Characteristics	
STUDY OBJECTIVE	To quantify the change in value for a subset of economic benefits (energy, capacity, ancillary services, DA forecasting error) that results from using renewable generation technologies (wind, PV, CSP, & Thermal Energy Storage) at different penetration levels.
GEOGRAPHIC FOCUS	Loosely based on California
SYSTEM CONTEXT	33% RPS, ISO market
LEVEL OF SOLAR ANALYZED	Up to 40% (by energy)
STAKEHOLDER PERSPECTIVE	System
GRANULARITY OF ANALYSIS	• Solar characterization - Hourly satellite derived insolation data from National Solar Research Database, 10 km x 10 km granularity, NREL SAM model • Marginal resource/losses characterization - For energy and capacity, modeled hourly market prices, reflecting day-ahead, real-time, and ancillary services • Geographic granularity - Not considered in this study
TOOLS USED	Customized model that evaluates long-run investment decisions and short-term dispatch and operations

Highlights

- The marginal economic value of solar exceeds the value of flat block power at low penetration levels, largely attributable to generation capacity value and solar coincidence with peak.
- The marginal value of DPV drops considerably as the penetration of solar increases, initially, driven by a decrease in capacity value with increasing solar generation. At the highest renewable penetrations considered, there is also a decrease in energy value as DPV displaces lower cost resources.
- The study notes that it is critical to use an analysis framework that addresses long-term investment decisions as well as short-term dispatch and operational constraints.
- Several costs and impacts are not considered in the study, including environmental impacts, transmission and distribution costs or benefits, effects related to the lumpiness and irreversibility of investment decisions, uncertainty in future fuel and investment capital costs, and DPV's capital cost.

OVERVIEW OF VALUE CATEG



Energy: Energy value decreases at high p
that DPV displaces changes as the syster
cost generator. Energy value is based on
hours (those hours where market prices a
displaces energy from a gas combined cy
Information Administration projections.

Generation Capacity: Generation capaci
profit earned during hours with scarcity pr
equals or exceeds $500/MWh). Effective
capacity credit as a result of the model's i
reliability or ELCC analysis.

Grid Support (Ancillary Services): Ancill
selling ancillary services in the market as
services due to increased short-term vari

Clean Power Research, 2012

The Value of Distributed Solar Electric Generation To New Jersey and Pennsylvan

Study Characteristics	
Study Objective	To quantify the cost and value components provided to utilities, ratepayers, and taxpayers by grid-connected, DPV in Pennsylvania and New Jersey.
Geographic Focus	7 cities across PA and NJ
System Context	PJM ISO
Level of Solar Analyzed	15% of system peak load, totaling 7 GW across the 7 utility hubs
Stakeholder Perspective	Utility, ratepayers, taxpayer
Granularity of Analysis	• Solar characterization - Hourly estimates based on SolarAnywhere (satellite-derived irradiance data and simulation model with a 10 km x 10 km pixel resolution) • Marginal resource/losses characterization - For energy and capacity, marginal resource assumed to be CT; Marginal loss savings calculated, although methodology unclear • Geographic granularity - Locational marginal price node
Tools Used	Clean Power Research's Distributed PV Value Calculator; Solar Anywhere, 2012

Highlights

- The study evaluated 10 benefits and 1 cost. Evaluated benefits included: Fuel cost savings, O&M cost savings, security enhancement, long term societal benefit, fuel price hedge, generation capacity, T&D capacity, market price reduction, environmental benefit, economic development benefit. The cost evaluated was the solar penetration cost.

- The analysis represents the value of PV for a "fleet" of PV systems, evaluated in 4 orientations, each at 7 locations (Pittsburgh, PA; Harrisburg, PA; Scranton, PA; Philadelphia, PA; Jamesburg, NJ; Newark, NJ; and Atlantic City, NJ), spanning 6 utility service territories, each differing by: cost of capital, hourly loads, T&D loss factors, distribution expansion costs, and growth rate.

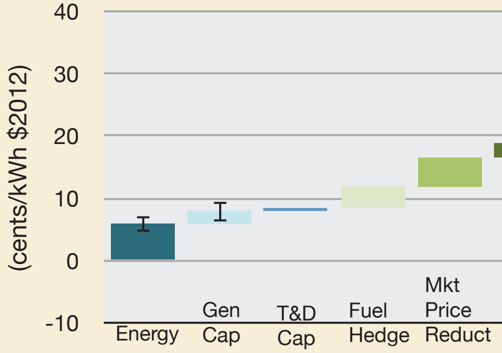
- The total value ranged from $256 to $318/MWh. Of this, the highest value components were the Market Price Reduction (avg $55/MWh) and Economic Development Value (avg $44/MWh).

- The moderate generation capacity value is driven by a moderate match between DPV output and utility system load. The effective capacity ranges from 28% to 45% of rated output (in line with the assigned PJM value of 38% for solar resources).

- Loss savings were not treated as a stand-alone benefit under the convention used in this methodology. Rather, the loss savings effect is included separately for each value component.

Overview of Value Categorie

Average Values



Energy: Fuel and O&M cost savings. PV output plus l for all hrs of the year, discounted over PV life (30 year O&M costs of the generator most likely operating on t turbine). Assumed natural gas price forecast: NYMEX 12 x 2.33% escalation factor. Escalation rate assume escalation from 1981-2011.

Generation Capacity: Capital cost of displace gener (ELCC), taking into account loss savings.

T&D Capacity: Expected long-term T&D system capa financial term, times a factor that represents match be T&D system load. In this study, T&D values were base obscure higher value areas.

Fuel Price Hedge Value: Cost to eliminate the fuel pr generation through procurement of commodity future capital.

Market Price Reduction: Value to customers of the r installation decreasing the demand for wholesale ener curve and reduction in demand, and the accompanyi

Security Enhancement Value: Annual cost of power high-demand stress type that can be effectively mitig

Social (Economic Development Value): Value of tax vs conventional power generation. PV hard and soft c jobs, divided by annual PV system energy produced, local jobs divided by annual energy produced. Leveliz for lost utility jobs, multiplied by tax rate of a $75K sal

Environmental: Environmental cost of a displaced co of this technology in the energy generation mix, repea sources displaced by PV. Environmental cost for each NOx emissions, mining degradations, ground-water c calculated in several environmental health studies.

CLEAN POWER RESEARCH & SOLAR SAN ANTONIO, 2013
THE VALUE OF DISTRIBUTED SOLAR ELECTRIC GENERATION TO SAN ANTONIO

STUDY CHARACTERISTICS	
STUDY OBJECTIVE	To quantify the value provided by grid-connected, DPV in San Antonio from a utility perspective.
GEOGRAPHIC FOCUS	CPS Energy territory
SYSTEM CONTEXT	Municipal utility
LEVEL OF SOLAR ANALYZED	1.1-2.2% of peak load (by capacity)
STAKEHOLDER PERSPECTIVE	Utility
GRANULARITY OF ANALYSIS	• Solar characterization - Hourly estimates based on SolarAnywhere (satellite-derived irradiance data and simulation model with a 10 km x 10 km pixel resolution) to provide time- and location-correlated PV output with utility loads • Marginal resource/losses characterization - For energy and capacity, marginal resource assumed to be an "advanced gas turbine"; losses calculated on marginal basis • Geographic granularity - Not specified
TOOLS USED	Clean Power Research's SolarAnywhere, PVSimulator, DGValuator

Highlights

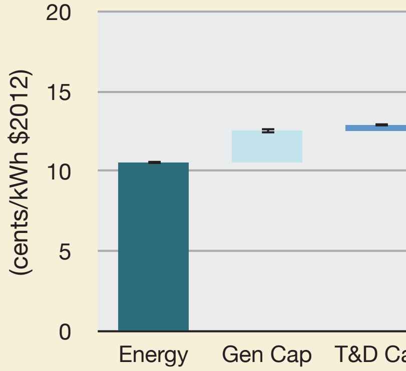
- The study concludes that DPV provides significant value to CPS Energy, primarily driven by energy, generation capacity deferment, and fuel price hedge value. The study is based solely on publicly-available data; it notes that results would be more representative with actual financial and operating data. Value is a levelized over 30 years.

- The study notes that value likely decreases with increasing penetration, although higher penetration levels needed to estimate this decrease were not analyzed.

- The study acknowledged but did not quantify a number of other values including climate change mitigation, environmental mitigation, and economic development.

OVERVIEW OF VALUE CATEG

AVERAGE VALU



Energy: The study shows high energy val
using EIA's "advanced gas turbine" with a
The natural gas price forecast is based or
escalated at a constant rate. Energy losse
calculated on an hourly marginal basis.

Generation Capacity: Generation capaci
fixed costs of an "advanced gas turbine",
Effective capacity based on ELCC; the rep
other studies. Every installed unit of DPV

T&D Capacity: The study takes a two ste
determine expansion plan costs and load
and second, an assessment of the correla
locations.

Fuel Price Hedge: The study estimates h
financial instruments, risk-free zero-coupo
contracts, to represent the avoided cost o

Environmental: The study quantified envi
above, but did not include it in its final ass
from the utility perspective.

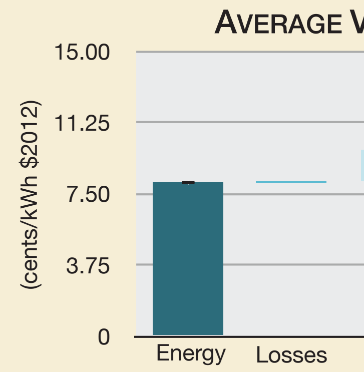
Austin Energy & Clean Power Research, 2006
The Value of Distributed Photovoltaics in Austin Energy and the City of Austin

Study Characteristics	
STUDY OBJECTIVE	To quantify the comprehensive value of DPV to Austin Energy (AE) in 2006 and document methodologies to assist AE in performing analysis as conditions change and, to apply to other technologies
GEOGRAPHIC FOCUS	Austin, TX
SYSTEM CONTEXT	Municipal utility
LEVEL OF SOLAR ANALYZED	>1% - 2%* system peak load
STAKEHOLDER PERSPECTIVE	Utility, ratepayer, participant, society
GRANULARITY OF ANALYSIS	• Solar characterization - Hourly PV output simulated for select PV configurations using irradiance data from hourly geostationary satellites; Validated using ground data from several climatically distinct locations including Austin, TX • Marginal resource/losses characterization - Energy: based on internal marginal energy cost provided by AE; • Geographic granularity - PV capacity value (ELCC) estimated system wide; Informed distribution avoided costs with area-specific distribution expansion plans "broken down by location and by the expenditure category"
TOOLS USED	Clean Power Research internal analysis; satellite solar data; PVFORM 4.0 for solar simulation; AE's load flow analysis for T&D losses

Highlights

- The study evaluated 7 benefits–energy production, line losses, generation capacity, T&D capacity, reactive power control (*grid support*), environment, natural gas price hedge (*financial*), and disaster recovery (*security*).
- The analysis assumed a 15 MW system in 7 PV system orientations, including 5 fixed and 2 single-axis.
- Avoided energy costs are the most significant source of value (about two-thirds of the total value), which is highly sensitive to the price of natural gas.
- Distribution capacity deferral value was relatively minimal. AE personnel estimated that 15% of the distribution capacity expansion plans have the potential to be deferred after the first ten years (assuming growth rates remain constant). Therefore, the study assumed that currently budgeted distribution projects were not deferrable, but the addition of PV could possibly defer distribution projects in the 11th year of the study period.
- Two studied values were excluded from the final results:
  - While reactive power benefits was estimated, the value ($0-$20/kW) was assumed not to justify the cost of the inverter that would be required to access the benefit (estimated cost not included).
  - The value of disaster recovery could be significant, but more work is needed before this value can be explicitly captured.

Overview of Value Cat



Energy: PV output plus loss savings
costs are based on fuel and O&M co
the margin (typically, a combined cy

System Losses: Computed differen
categories, loss savings are calculat

Generation Capacity: Cost of capa
capability (ELCC), taking into accou

Fuel price Hedge: Cost to eliminate
natural gas generation through proc
hedge value is included in the energ

T&D Capacity: Expected long-term
by load growth, times financial term
between PV system output (adjusted

Environmental: PV output times RE
unit of conventional generation.

*ELCC was evaluated from 0%-20%
penetration was used in final value.

Austin Energy & Clean Power Research, 2012

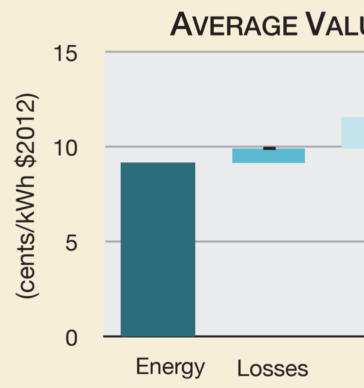
Designing Austin Energy's Solar Tariff Using A Distributed PV Calculator

Study Characteristics	
Study Objective	To design a residential solar tariff based on the value of solar energy generated from DPV systems to Austin Energy
Geographic Focus	Austin, TX
System Context	Municipal utility with access to ISO (ERCOT)
Level of Solar Analyzed	Assumed to be 2012 levels of penetration (5 MW)[1] < 0.5% penetration by energy[2]
Stakeholder Perspective	Utility
Granularity of Analysis	Assumed to replicate granularity of AE/CPR 2006 study
Tools Used	Clean Power Research's Distributed PV Value Calculator; Solar Anywhere, 2012

Highlights

- The study focused on 6 benefits–energy, generation capacity, fuel price hedge value (included in energy savings), T&D capacity, and environmental benefits–which represent "a 'break-even' value...at which the utility is economically neutral to whether it supplies such a unit of energy or obtains it from the customer." The approach, which builds on the 2006 CPR study, is "an avoided cost calculation at heart, but improves on [an avoided cost calculation]... by calculating a unique, annually adjusted value for distributed solar energy."
- The fixed, south-facing PV system with a 30-degree tilt, the most common configuration and orientation in AE's service territory of approximately 1,500 DPV systems, was used as the reference system.
- As with the AE/CPR 2006 study, avoided energy costs are the most significant source of value, which is very sensitive to natural gas price assumptions.
- The levelized value of solar was calculated to total $12.8/kWh.
- Two separate calculation approaches were used to estimate the near term and long term value, combined to represent the "total benefits of DPV to Austin Energy" over the life time of a DPV system.
  - For the the near term (2 years) value of DPV energy, A PV output weighted nodal price was used to try to capture the relatively good correlation between PV output and electricity demand (and high price) that is not captured in the average nodal price.
  - To value the DPV energy produced during the mid and long term–through the rest of the 30-year assumed life of solar PV systems–the typical value calculator methodology was used.

Overview of Value Cate



Energy: DPV output plus loss savings
costs are based on fuel and O&M cost
margin (typically, a combined cycle ga

System Losses: Computed differently
categories, loss savings are calculate

Generation Capacity: Cost of capacit
(ELCC), taking into account loss savin

Fuel Price Hedge Value: Cost to elimi
natural gas generation through procur
value is included in the energy value.

T&D Capacity: Expected long-term T
load growth, times financial term, time
system output (adjusted for losses) an

Environmental: PV output times Rene
incremental cost of offsetting a unit of

Sources:
1) http://www.austinenergy.com/Abou
solarGoalsUpdate.pdf
2) http://www.austinenergy.com/Abou
2012AnnualPerformanceReportDRAF

Navigant Consulting for NREL, 2008
Photovoltaics Value Analysis

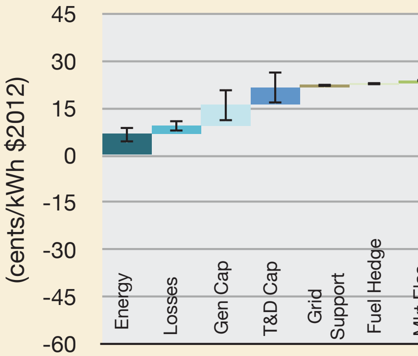
Study Characteristics	
STUDY OBJECTIVE	To summarize and describe the methodologies and range of values for the costs and values of 19 services provided or needed by DPV from existing studies.
GEOGRAPHIC FOCUS	Studies reviewed reflected varying geographies; case studies from TX, CA, MN, WI, MD, NY, MA, and WA
SYSTEM CONTEXT	n/a
LEVEL OF SOLAR ANALYZED	n/a
STAKEHOLDER PERSPECTIVE	Participating customers, utilities, ratepayers, society
GRANULARITY OF ANALYSIS	This study is a meta-analysis, so reflects a range of levels of granularity.
TOOLS USED	Custom-designed Excel tool to compare results and sensitivities

Highlights

- There are 19 key values of distributed PV, but the study concludes that only 6 have significant benefits (energy, generation capacity, T&D costs, GHG emissions, criteria air pollutant emissions, and implicit value of PV).
- Deployment location and solar output profile are the most significant drivers of DPV value.
- Several values require additional R&D to establish a standardized quantification methodology.
- Value can be proactively increased.

OVERVIEW OF VALUE CATEG

AVERAGE VALU



Energy: Energy value is fuel cost times the h
power plant, generally assumed to be natura

System Losses: Avoided loss value is the ar
generation capacity, T&D capacity, and envir

Generation Capacity: Generation capacity v
power plant times the effective capacity (ELC

T&D Capacity: T&D capacity value is T&D in
money times the effective capacity, divided b

Grid Support Services (Ancillary Services):
load following, operating reserves, and dispa
able to provide all of these.

Financial (Fuel Price Hedge, Market Price
guarantee a portion of electricity costs are fix
decreases the price of electricity for all custo

Security: Customer reliability in the form of in
but only when DPV is coupled with storage.

Environment (Criteria Air Pollutants, Carbo
penalties or costs, or the value of avoided he
value is the emission intensity of the margina

Customer: Value to customer of having gree
pay.

Solar cost: Costs include capital cost of equ
maintenance costs.

SOURCES

05

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SAIC. 2013 Updated Solar PV Value Report. Arizona Public Service. May, 2013.	Arizona Public Service	SAIC
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ACRONYMS

AE - Austin Energy
APS - Arizona Public Service
AS - Ancillary Services
CCGT - Combined Cycle Gas Turbine
CHP - Combined Heat and Power
CPR - Clean Power Research
CT - Combustion Turbine
DER - Distributed Energy Resource
DPV - Distributed Photovoltaics
E3 - Energy + Environmental Economics
eLab - Electricity Innovation Lab
ELCC - Effective Load Carrying Capacity
FERC - Federal Energy Regulatory Commission
ISO - Independent System Operator
LBNL - Lawrence Berkeley National Laboratory
NREL - National Renewable Energy Laboratory
NYMEX - New York Mercantile Exchange
PV - Photovoltaic
RMI - Rocky Mountain Institute
SDG&E - San Diego Gas & Electric
SEPA - Solar Electric Power Association
SMUD - Sacramento Municipal Utility District
T&D - Transmission & Distribution
TOU - Time of Use

Exhibit DG-3

THE MENDOTA GROUP, LLC

the power of bright ideas

Benchmarking Transmission and Distribution Costs Avoided by Energy Efficiency Investments

for Public Service Company of Colorado

October 23, 2014

Table of Contents

Executive Summary

Energy efficiency (EE) program cost-effectiveness evaluations assess the value (benefits) of these programs to a utility's system and aim to determine whether benefits exceed costs. The value of the generation and delivery system investments *avoided* or *deferred* by EE are components of the estimates of such benefits. Although estimates of avoided investments in and operation of generating units are fairly straightforward and tend to focus on a limited number of types of such units estimates of avoided investments in and operation of transmission and distribution (T&D) system components tend to be less straightforward. The following analysis examines ways in which utilities in the United States estimate EE program avoided transmission and distribution costs and provides a survey of current estimates.

Utilities have used a number of methods for estimating avoided T&D and there is no one "best" approach to developing these estimates. This report conducts a fairly broad benchmarking study of other utilities' estimates of avoided T&D costs. The benchmarking study produced a wide range of estimates for avoided T&D, underscoring the diverse nature of the methods used to calculate avoided costs. Although the process of estimating avoided transmission and distribution costs for EE programs has a long history it appears that it remains a dynamic area that will continue to evolve in the years to come. With this in mind, it would serve PSCo well to revisit this issue in the coming years.

A. Study Purpose

Xcel Energy (the "Company" or "PSCo") uses estimates of transmission and distribution facilities avoided or deferred by investments in energy efficiency in its EE cost-effectiveness evaluations. However, these estimates were developed nearly 10 years ago. It is useful at this point to refresh the Company's understanding of the way that U.S. utilities are calculating their avoided T&D for use with EE program cost-benefit analyses. The Company has requested assistance in researching other utilities' T&D estimates and the basis for those values.

To this end, the consultants sought to accomplish the following tasks:

- **Task 1. Research methods of estimating avoided T&D costs –** Consultant will survey methods used in most recent estimates of T&D avoided costs.
- **Task 2. Identify comparable utilities/systems and benchmark –** Consultant will identify at least five comparable utilities with which to compare and benchmark estimates for the Company.
- **Task 3. Conduct surveys/research of comparable utilities –** T&D cost assumptions and the methodologies used to derive them are often not readily available through publicly available information. Thus, Consultant may need to contact some of utilities to determine avoided T&D information.

The following report is the product of these tasks and seeks to answer each of the questions raised.

B. Issue Overview

Utility-administered electric energy efficiency programs benefit utility ratepayers by reducing the amount of electricity end-use customers consume for a given amount of production (e.g. lumens, cooling load, production from an assembly line, etc.). For the utility, this reduced electricity use translates to less electricity that its power plants must produce (or that the utility must purchase) to meet customer requirements. Over the longer term, it also reduces the need to construct new or expand existing generating facilities. These investments in end-user energy efficiency may also reduce the T&D system capacity needed to transport electricity from power plants to customers.

With respect to T&D systems, it is feasible that EE can avoid or delay T&D upgrades, and reduce construction and associated operations and maintenance costs, including cost of capital, taxes and insurance. If EE measures help reduce demand during peak periods, EE investments can also reduce the timing of maintenance, because frequent peak loads at or near design capacity will reduce the life of some types of T&D equipment.[1]

EE program administrators typically use estimates of investments in generation, transmission, and distribution (GT&D) "avoided" to calculate the cost-effectiveness of investments in energy efficiency programs. According to the *California Standard Practice Manual,* "the benefits calculated in the Total Resource Cost Test are the avoided supply costs, the reduction in transmission, distribution, generation, and capacity costs valued at marginal cost for the periods when there is a load reduction."[2] The *National Action Plan for Energy Efficiency* (NAPEE) explains,

> The resource benefits of energy efficiency fall into two general categories:
> (1) Energy-related benefits that affect the procurement of wholesale electric energy and natural gas, and delivery losses,
> (2) Capacity-related benefits that affect wholesale electric capacity purchases, construction of new facilities, and system reliability.[3]

However, while estimates of avoided supply costs associated with the reduction in generation and capacity costs have more narrowly focused on capacity costs associated with a natural gas-fueled combustion turbine (CT) generating unit (and occasionally a combined cycle unit) and system-wide marginal energy costs,[4] estimates of avoided costs associated with T&D have varied

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[1] "Assessing the Multiple Benefits of Clean Energy, A Resource for States," U.S. Environmental Protection Agency, Revised September 2011, p. 75.

[2] "California Standard Practice Manual: Economic Analysis of Demand-Side Programs and Projects," California Public Utilities Commission, October 2001, p. 18.

[3] "National Action Plan for Energy Efficiency," U.S. Department of Energy, U.S. Environmental Protection Agency, July 2006, p. 3-3.

[4] "Best Practices in Energy Efficiency Program Screening," Synapse Energy Economics for National Home Performance Council, July 23, 2012, p. 23. In some states, administrative rules dictate what type of generating unit will be used to calculate costs (see Iowa and Texas as examples).

widely. Although some of this variation may result from actual cost differences between utilities, much appears to also relate to variations in the way utilities calculate such costs.

Estimating avoided transmission and distribution costs is inherently more complex than generation because T&D benefits from EE tend to be location-specific, system-wide and time dependent. In other words, large amounts of EE investment in a specific part of the distribution grid could more significantly impact, say, required upgrades to a specific substation. On the other hand, system-wide energy efficiency investments can effectively reduce overall loading on transmission and distribution lines but still may not affect T&D investments unless the measures are coincident with system peaks.

Transmission and distribution systems are designed to carry extreme peak loads, which increases costs. States that use marginal cost of service studies to set rates regularly look at the cost to add T&D capacity. Put plainly,

> The capital cost of augmenting transmission capacity is typically estimated at \$200 to \$1,000 per kilowatt and the cost of augmenting distribution capacity ranges between \$100 and \$500 per kilowatt. Annualized values (the average rate of return multiplied by the investment over the life of the investment) are about 10% of these figures, or \$20 to \$100 per kilowatt-year for transmission and \$10 to \$50 per kilowatt-year for distribution. There are also marginal operations and maintenance costs for transmission and distribution capacity, but these are modest in comparison to the capital costs.[5]

But not all forecast T&D investments are deferrable or avoidable. "Some will be required to address time-related deterioration of equipment or other factors that are independent of load."[6] One of the primary drivers of investment is the growth in the number of customers, which is not avoidable load growth. Other investments only a portion of which may be deferrable/avoidable from EE include modernization projects to improve technology, reliability improvements related to changes in reliability or safety standards, and projects to accommodate non-native load or supply, among others.

Authors Chris Neme and Rich Sedano categorize the manner in which efficiency programs can defer T&D investments as "passive" or "active". Passive refers to deferred investments in transmission and distribution that occur as a byproduct of EE investments whereas active deferrals are those that result from EE initiatives targeted at specific locations. Active deferrals have the express purpose of deferring T&D investments. The authors cite a host of reasons as to why active deferrals are uncommon.[7]

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[5] "Valuing the Contribution of Energy Efficiency to Avoided Marginal Line Losses and Reserve Requirements," Jim Lazar, Xavier Baldwin, Regulatory Assistance Project, August 2011, p. 6.

[6] "US Experience with Efficiency As a Transmission and Distribution System Resource," Chris Neme (Energy Futures Group), Rich Sedano (Regulatory Assistance Project), February 2012, p. i.

[7] "US Experience with Efficiency As a Transmission and Distribution System Resource," p. i. Among the reasons active deferrals lack popularity are: utility disincentives, difficulty in conducting T&D planning holistically, technical limitations, system engineers biased against demand resources, and risk aversion, among others.

Further to this point, "passive deferral occurs when the growth in load or stress on feeders, substations, transmission lines, or other elements of the T&D system is reduced as a result of broad-based (e.g., statewide or utility service territory-wide) efficiency programs."[8] Estimates of savings from EE investments "are typically developed by dividing the portion of forecast T&D capital investments that are associated with load growth (i.e., excluding the portion that is associated with replacement due to time-related deterioration or other factors that are independent of load) by the forecast growth in system load."[9] Section C discusses in more detail the different ways that utilities estimate avoided transmission and distribution costs.

It bears repeating that investments in transmission and distribution systems have other benefits beyond meeting load growth, including providing reliable service and meeting the needs of a growing number of customers. Investments in system improvements can also provide production cost savings through reduced line losses and reduced congestion, generation capacity cost savings by providing access to lower cost resources, and increased employment activities, among others.[10] This is relevant because it points out that while energy efficiency investments may defer or avoid transmission and distribution investments that such investments may provide other benefits that contribute (and are economically valuable) to the electricity system (thereby arguing that avoided cost estimates may be mitigated somewhat by ancillary benefits associated with these improvements). The next section discusses some common methods for calculating avoided T&D costs.

C. Common T&D Avoided Cost Calculation Methodologies

As previously discussed, there is little consistency between jurisdictions in terms of how avoided T&D costs are calculated. Unlike estimates of avoided energy and generating capacity, estimates of avoided T&D tend to require a fair amount of subjectivity in determining what to include in and what to exclude from calculations. Each utility has a different take on the topic and regulators to the extent they become involved in the issue also differ. Some utilities do not include estimates of avoided T&D in their evaluations, believing that EE does not defer T&D investments.[11] Other utilities, like those in Idaho, may include avoided transmission costs in calculations but place the value at zero because the generating unit avoided is close to load, thereby deferring no transmission.[12]

As such, determining what constitutes "best practice" becomes difficult, particularly because none of the different approaches are necessarily *wrong*. It is just that there are a variety of methods for developing the estimates, and each may be capable of producing valid estimates.

[8] "US Experience with Efficiency As a Transmission and Distribution System Resource," p. 3.

[9] "US Experience with Efficiency As a Transmission and Distribution System Resource," p. 3.

[10] "The Benefits of Electric Transmission: Identifying and Analyzing the Value of Investments," The Brattle Group, July 2013, p. 10.

[11] See "Consumers Energy: 2012-2015 Amended Energy Optimization Plan," Submitted to Michigan Public Service Commission (Case No: U-16670), August 1, 2011, p. 25.

[12] "Reviving PURPA's Purpose: The Limits of Existing State Avoided Cost Ratemaking Methodologies in Supporting Alternative Energy Development and A Proposed Path for Reform," Prepared by Carolyn Elefant, 2011, p. 31.

The uncertainty stems, in part, from the nature of energy efficiency as relying upon the counterfactual (i.e., the determination of what would have happened on the system if the EE program did not exist). To devise an analytical tool that enables one to assess the benefits and costs of EE requires that practitioners develop "good" estimates of the benefits EE investments produce. Good estimates are those based on sound principles as discussed in the following sections. The following section outlines a number of the methods while Appendix A provides an assessment of the strengths and weaknesses of the different approaches. Section D follows with a survey of a number of utilities' avoided cost estimates.

a. System Planning Approach

According to the U.S. Environmental Protection Agency's (EPA's) "Assessing the Multiple Benefits of Clean Energy (September 2011)," the *system planning approach* is the best way to estimate avoided T&D costs. "The system planning approach uses projected costs and projected load growth for specific T&D projects based on the results from a system planning study—a rigorous engineering study of the electric system to identify site-specific system upgrade needs. Other data requirements include site-specific investment and load data. This approach assesses the difference between the present value of the original T&D investment projects and the present value of deferred T&D projects."[13]

The U.S. EPA endorses this approach and suggests use of proprietary models of T&D system operation (two cited are PowerWorld Corp's model and the Siemens [PSS®E] model) to identify location and timing of system stresses. The system planning approach may well be the best way to estimate avoided T&D costs; however, the approach seems primarily to have been used to analyze investments in specific T&D projects rather than to analyze the system as a whole. The approach has been used to estimate the value of distributed generation and energy efficiency at ConEdison, Bonneville Power Administration, Efficiency Vermont, Detroit Edison, and Southern California Edison, among others.[14] However, these projects all appear to be aimed at "active" deferrals rather than the more typical passive deferrals.

b. Mix of Historical and Forecast Information Approach[15]

The ICF Tool, developed by ICF International, Inc. best exemplifies the Mix of Historical and Forecast Information approach. ICF developed a calculation methodology as part of a 2005 report prepared for the Avoided-Energy-Supply-Component (AESC) Study Group, whose members included utilities in Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont.[16] The report was commissioned to review energy supply costs avoided in the Northeast through energy efficiency programs. The AESC report has been updated biennially since 2005, but there have been no substantive changes to the calculator.

At its core, the ICF Tool collects data on historical and forecast T&D investments, determines what portions are due to load growth, and weights the historical and forecast contributions to

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[13] "Assessing the Multiple Benefits of Clean Energy," p. 76.

[14] "Best Practices in Energy Efficiency Program Screening," p. 25.

[15] This is a made-up label. Some have called this "projected embedded cost analysis" (see "Best Practices in Energy Efficiency Program Screening," p. 24.

[16] "Avoided Energy Supply Costs in New England: 2005 Report," Prepared for Avoided-Energy-Supply-Component (AESC) Study Group by ICF Consulting, December 23, 2005.

arrive at transmission and distribution T&D capacity marginal costs in $/kW-year. The tool takes the form of an Excel spreadsheet with four schedules (Schedule 1 is a summary) and an appendix. The Tool recommends that the user input 15 years of historical data and 10 years of forecast data for T&D capital investments and peak load. In addition, the user must input a variety of values from their FERC Form 1, including: property taxes, insurance costs, and operation and maintenance expenses. The user must also estimate the portions of investments identified in FERC Form 1 that are related to increasing load.[17]

The benefits of this methodology are that the Tool is well established, much of the data is available through FERC Form 1, and utilities and Commissions in the Northeast have been vetting it for nearly ten years. Many utilities continue to use the approach. The concerns with this method are that despite data being available from the FERC Form 1, the Tool still requires the user to make a subjective analysis of the proportion of investments resulting from increasing load. In addition, the 2009 AESC Report pointed out a number of potential calculation errors in the spreadsheet.[18]

c. Current Values Approach

The Current Values approach is well exemplified by MidAmerican Energy Company in its multiple state demand-side management (DSM) filings. MidAmerican has a standardized approach to calculating T&D capacity avoided costs in each of the states where it offers energy efficiency programs including Iowa, Illinois and South Dakota. This methodology is detailed in the direct testimony of Jennifer L. Long, in Iowa Docket No. EEP-2012-0002.

MidAmerican calculates T&D avoided costs as follows,

> The average cost to serve existing load is calculated for both the transmission and distribution systems by dividing each system's net cost by each system's peak capability. MidAmerican's Federal Energy Regulatory Commission (FERC) Form 1 data is used to calculate the net costs of the transmission and distribution systems by taking MidAmerican's original cost of plant less accumulated depreciation for each respective system. Yearly, MidAmerican load data and generation capability data is used to approximate the capacity of each system. The end result of the calculation is a $/kW cost for each system.[19]

The biggest strength of this method is its simplicity, which lends itself to frequent updates.

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[17] FERC Form 1, submitted annually by large utilities, provides comprehensive financial and operating results of the utility for the previous year. Investments specifically targeted for addressing load growth are not identified therein.

[18] "Avoided Energy Supply Costs in New England: 2009 Report," Prepared for Avoided-Energy-Supply-Component (AESC) Study Group by Synapse Energy Economics, Inc., August 21, 2009, p. 6-67.

[19] "Direct Testimony of Jennifer L. Long," Application for Approval of Energy Efficiency Plan for 2014-2018 (Docket EEP-2012-0002), Submitted to Iowa Public Utilities Board by MidAmerican Energy Company, Feb. 1, 2013, p. 4. Note that MidAmerican modified its approach to incorporate on peak load data instead of generation capability data.

d. Rate Case Marginal Cost Data with Allocators Approach

There are a few variations on the theme of using most recent marginal cost of service data from the utility rate case to develop estimates of avoided transmission and distribution costs. In California, T&D avoided costs are considered unique among other types of avoided costs in that both the value and hourly allocations are location specific. This information is combined with utility rate case information to calculate avoided costs separately for each utility.

As discussed in the 2011 update to the state's avoided costs,

> … the value of deferring distribution investments is highly dependent on the type and size of the equipment deferred and the rate of load growth, both of which vary significantly by location. Furthermore, some distribution costs are driven by distance or number of customers rather than load and are therefore not avoided with reduced energy consumption. However, expediency and data limitations preclude analysis at a feeder-by-feeder level for a statewide analysis of avoided costs. The costs taken from utility rate case filings are used as a reasonable proxy for the long-run marginal cost T&D investment that is avoided over time ...[20]

The avoided cost calculations also allocate T&D capacity values in each climate zone to the hours of the year during which the system is most likely to be constrained and require upgrade (the hours of highest local load). Although these values were previously based on hourly temperature values for the individual climate zones the information has since been updated for cost-effectiveness calculators (but not yet incorporated into the EE calculator) due to the availability of utility information on actual substation load data.[21]

e. Rate Case Marginal Cost Data Approach

Ameren Missouri goes through a fairly detailed review of its distribution and transmission system investments to determine the marginal cost of system capacity as it relates to load growth. However, this is complicated by the fact that "projects serve a variety of purposes; capacity upgrades to serve incremental system load, capacity upgrades to serve relocated system load, and refurbishment or replacement of equipment to avoid imminent failure."[22] As Ameren points out, analyzing the system in aggregate rather than focusing on specific areas further complicates the estimates, mainly because energy efficiency programs are designed to target specific areas.

PacifiCorp includes avoided T&D credits in its assessment of resources as part of its IRPs filed in Oregon, Washington, Idaho, California, Wyoming, and Utah. Specifically, PacifiCorp uses a cost of service study to derive the estimates. As part of the study, PacifiCorp estimates the demand-related substation costs by taking the total substation capacity expansion investment for the subsequent five years, dividing by the total increased capacity in kVA and then annualizing this number by multiplying by a carrying charge. The method of estimating demand-related transmission costs is similar. All "growth-related" transmission investment (with some

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[20] "Energy Efficiency Avoided Costs 2011 Update," by Brian Horii, Eric Cutter (Energy and Environmental Economics, Inc.), December 19, 2011, p. 24.

[21] "Energy Efficiency Avoided Costs 2011 Update," p. 26.

[22] "Ameren Missouri - 2011 Integrated Resource Plan," File No. EO-2011-0271, February 23, 2011.

exceptions like bulk power lines) over the subsequent five years is divided by the forecasted change in peak over the same period and this value is annualized.[23]

In its 2013 IRP, Nevada Energy uses the marginal cost study associated with the utility's 2010 rate case (Docket No. 10-06001) to determine its avoided T&D costs. As the utility states in its filing, "the adopted valuation process reduces potential difficulties regarding uncertainty in load forecasts and T&D construction budgets, and takes into account the ripple effect or the effect of deferred construction investments during the useful life of energy efficiency measures."[24] The Company, in turn, utilizes the conservative value of 25 percent of $47.50/kW (annual revenue requirement for the marginal cost of transmission facilities and distribution system, not accounting for the distribution beyond substation) or $11.88/kW in cost effectiveness analysis, and escalates it in each year by applying a cost construction index. The company further acknowledged that this is a low value when compared to other states like California.

Selection of Other Approaches

Averaging Method

In a note to the Vermont Public Service Board, a consultant outlines the various options available for calculating avoided T&D costs and cites among the options the "New England Average Method."[25] This method proposes using a New England average avoided T&D cost of $83 calculated from the figures identified in the 2011 AESC report. Although Vermont did not adopt this method other utilities have used a similar approach. Wisconsin Focus on Energy, which does not have explicit avoided T&D costs in its cost-effectiveness calculations, used an Iowa average for its market potential study.[26] In the Pacific Northwest, the Northwest Conservation and Electric Power Plan uses an average of avoided costs from a selection of utilities.[27]

IRP Approach

Some utilities use a variant of the System Planning Approach by conducting with and without DSM analyses to estimate avoided T&D costs.[28] Tucson Electric Power (TEP) conducts a decrement study to assess how transmission costs are avoided and uses this calculation in the utility's EE cost-effectiveness evaluations. It does not appear that TEP includes avoided distribution costs in its calculations and the utility only publishes its total avoided capacity costs. The utility considers the details proprietary and, therefore, specific information is not available.

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[23] Correspondence with PacifiCorp representatives, August 22, 2014.

[24] Sierra Pacific Power Company d/b/a NV Energy Integrated Resource Plan 2014-2033, Demand Side Plan 2014-2016," p. 48.

[25] "List of Possible Methods for Determining Avoided Transmission and Distribution Costs," Submitted to Vermont Public Service Board, June 28, 2012, http://psb.vermont.gov/docketsandprojects/eeu/avoidedcosts/2011.

[26] "Minutes and Informal Instructions of the Open Meeting of Thursday, July 10, 2014," Public Service Commission of Wisconsin, p. 3.

[27] "Appendix E – Conservation Supply Curve Development" in Sixth Northwest Conservation and Electric Power Plan, February 1, 2010, p. E-13, https://www.nwcouncil.org/energy/powerplan/6/plan/.

[28] This version of the System Planning Approach is more frequently associated with calculations of avoided generation energy and capacity costs. See "The Role and Nature of Marginal and Avoided Capacity Costs in Ratemaking: A Survey," Hethie Parmesano and William Bridgman, National Economic Research Associates, January 1992, p. 13.

Others
The memo to the Vermont Public Service Board also identified a method termed the "Simple Method" which relies on taking representative samples of recent T&D upgrade projects, dividing by increased capacity and annualizing.[29] The formula follows:

(Cost of Upgrades) ÷ (Additional Capacity Achieved by the Upgrade) ÷ (Economic Life of Upgrade)

A final method entails looking at each potential cost category of T&D capital costs and operations and maintenance expenses and making educated guesses as to the percentage of the cost category that is deferrable by EE. This can be applied to historical and, if available, forecast costs to determine the annualized value as it applies to load growth.

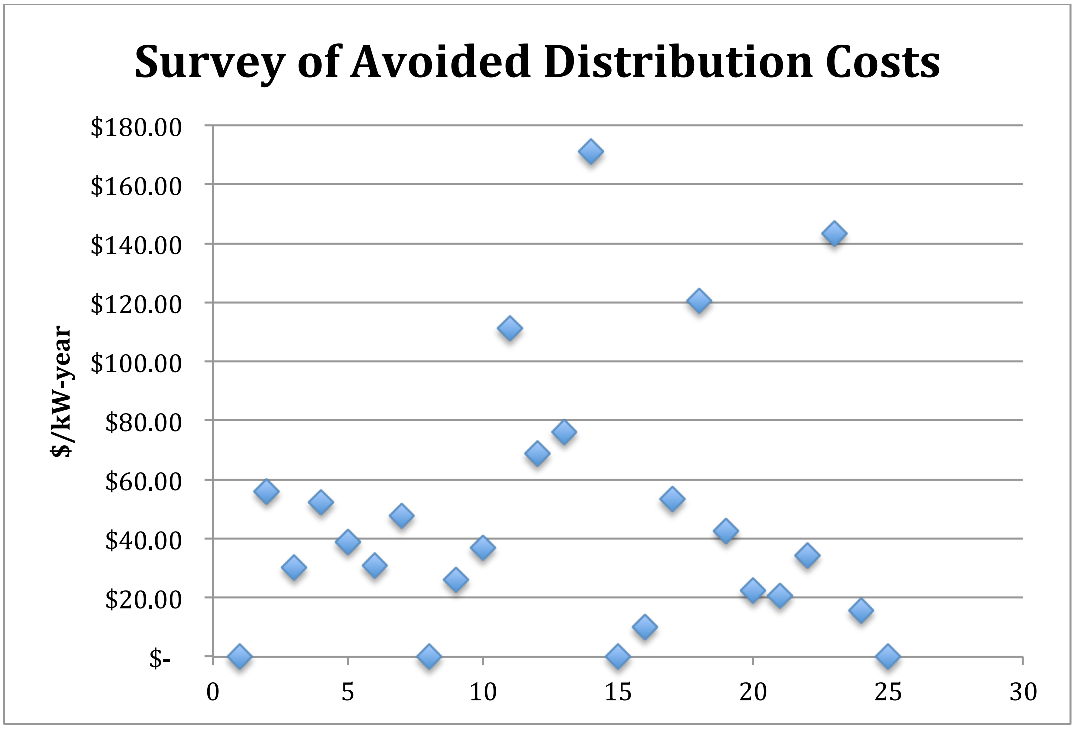
D. Survey of Other Utilities / Benchmarking

As part of Tasks 2 and 3, the authors collected avoided T&D data from a fairly broad cross-section of utilities. Data collection efforts sought to maximize the number of data points while also making an attempt to include utilities that might be most relevant to PSCo. However, it is unclear whether utility size or region has any bearing on estimated avoided costs and, therefore, the effort did not concentrate on the Rocky Mountain region or on comparably sized utilities. The survey does include some results from mountain states such as Arizona, Utah, Idaho and Nevada and also includes information from comparably sized (customers, sales) utilities (Consumers Energy [MI], Northern States Power [MN], Arizona Public Service [AZ]). Appendix B provides the detailed results of the survey. The range of data points for avoided Distribution cost estimates are provided below. The first section focus on distribution system estimates and it is followed by estimates of transmission system avoided costs. Combined estimates of avoided T&D are included in the final section.

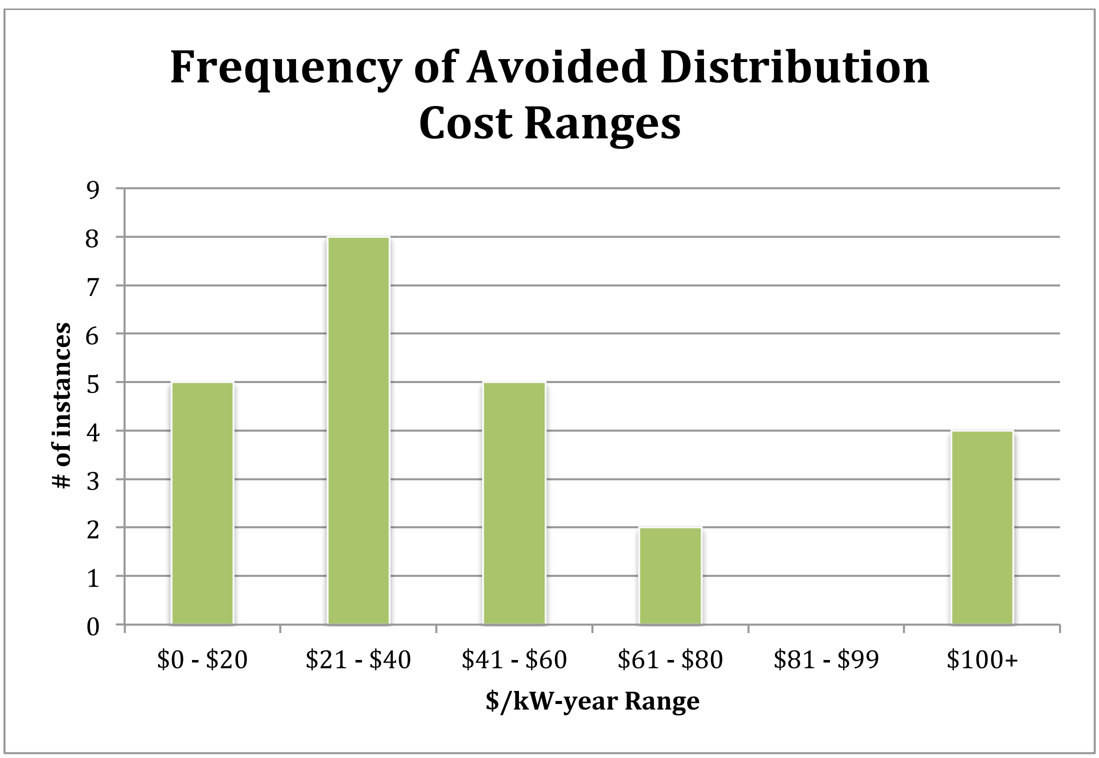
Estimates of Distribution System Avoided Costs

The average avoided distribution costs are $48.37 with a range from $0 to $171/kW-year.

[29] "List of Possible Methods for Determining Avoided Transmission and Distribution Costs," p. 2.

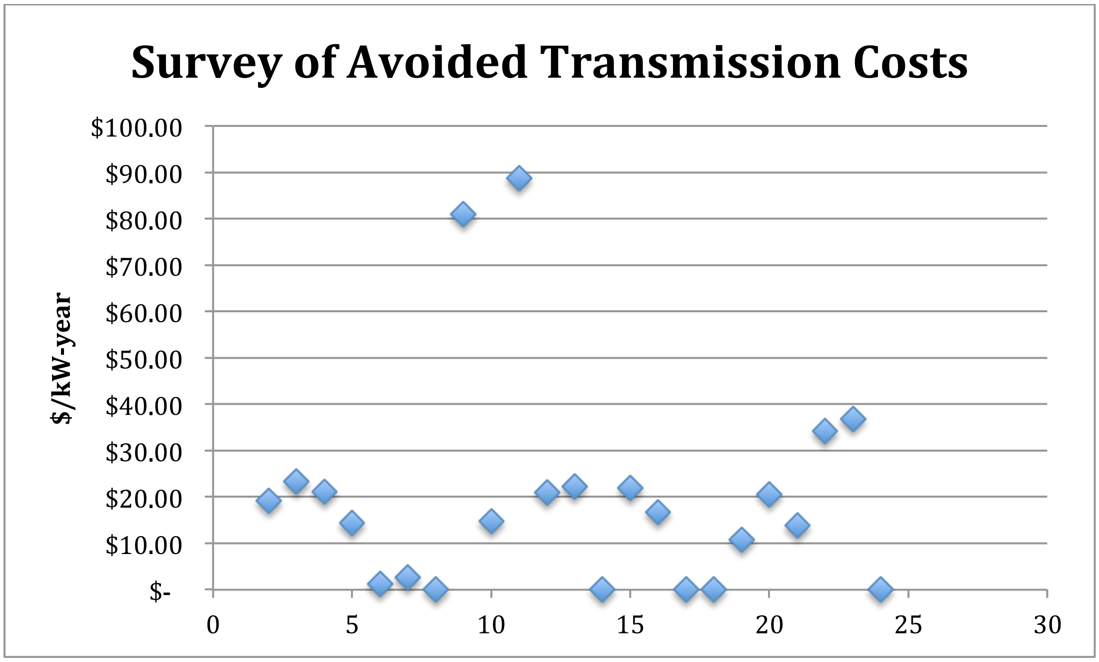


The values are most heavily concentrated in the $21 to $40 range with 8 of the samples falling in this range.

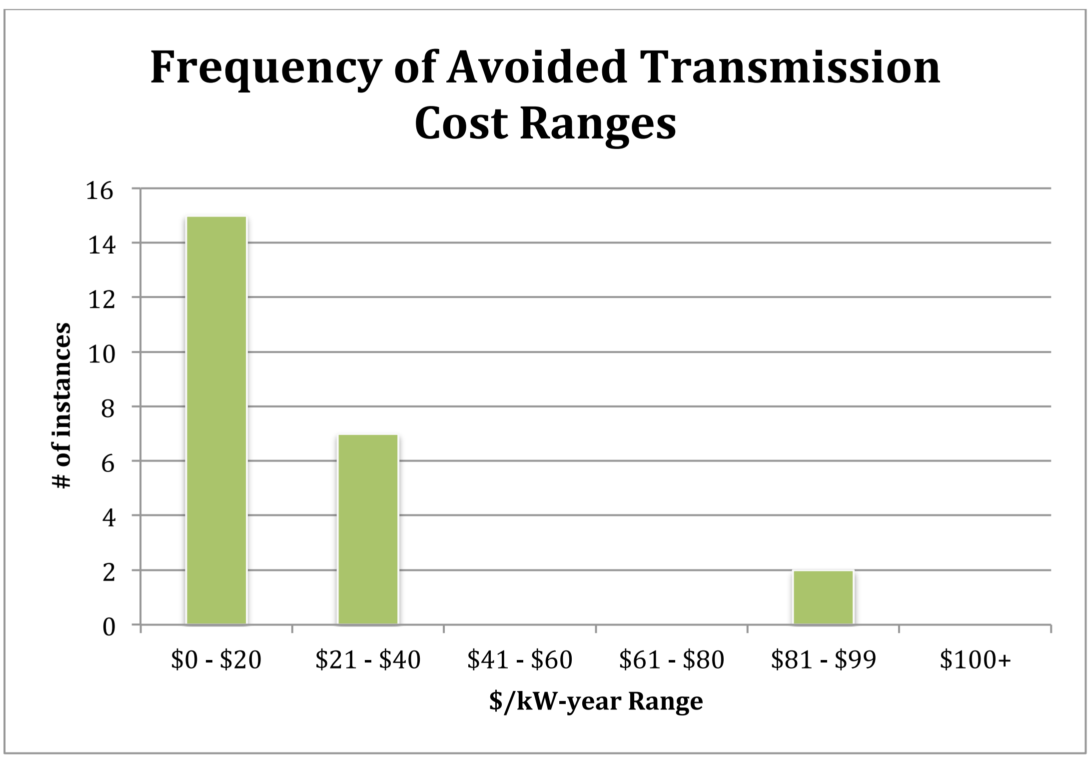


Estimates of Transmission System Avoided Costs

Average avoided transmission costs are $20.21 with a range from $0 to $88.64/kW-year.

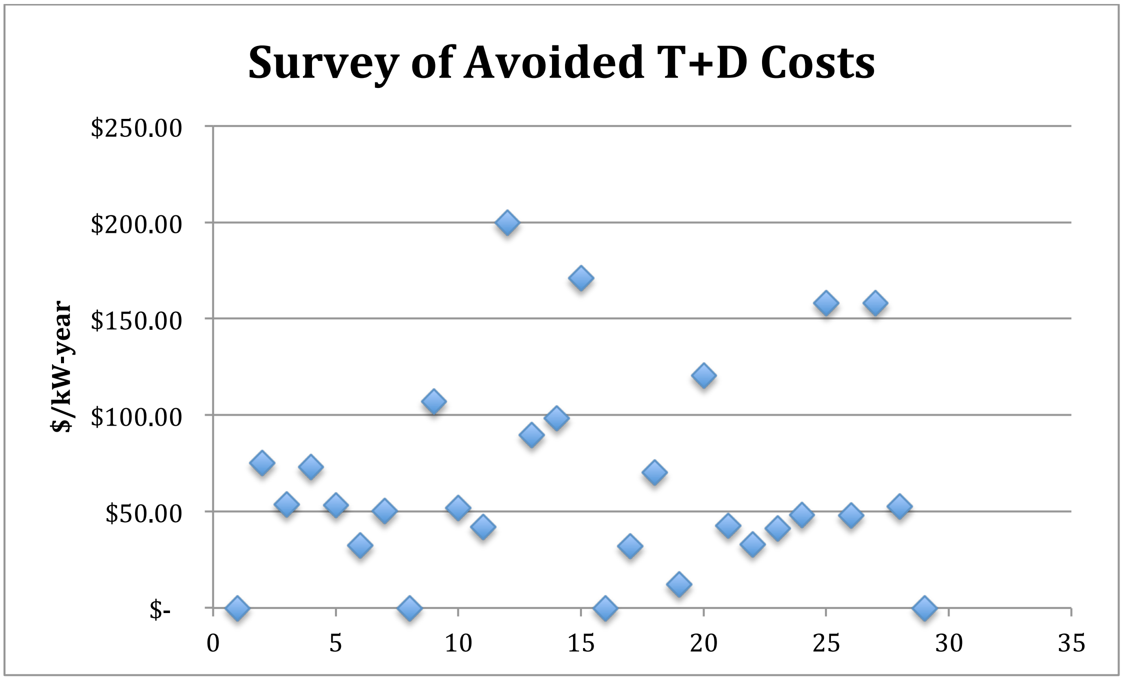


Transmission values are most heavily concentrated in the $0 to $20 range with 15 of the samples falling in this range

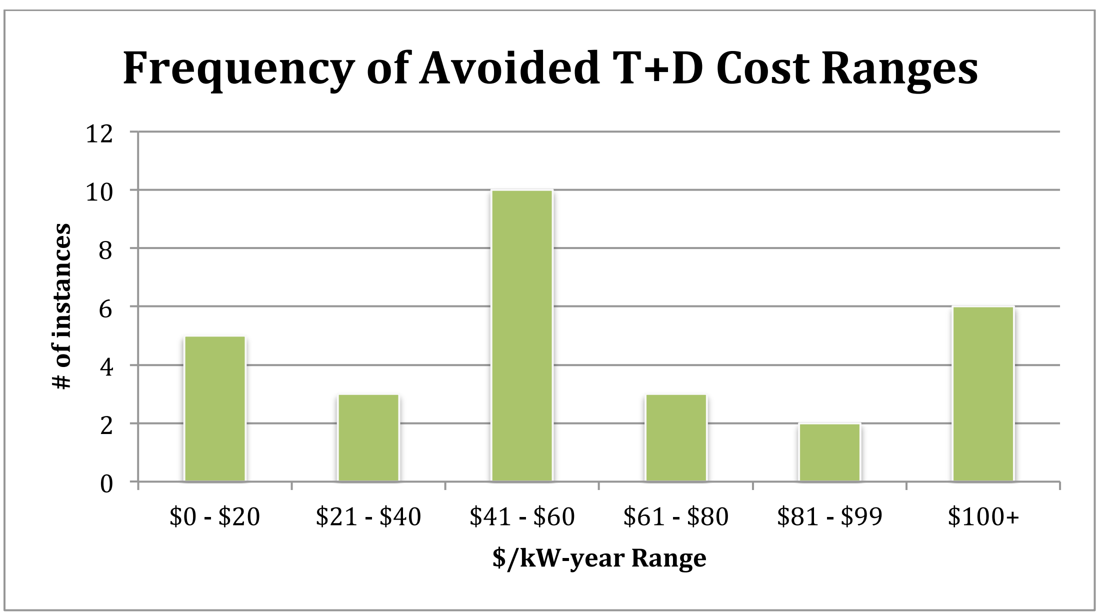


Estimates of T&D System Avoided Costs

Finally, the average avoided transmission + distribution costs are $66.03 with a range from $0 to $200.01/kW-year. It should be noted that there are more combined T&D results because some utilities did not break out T&D.



The values are most heavily concentrated in the $41 to $60 range with 10 of the samples falling in this range.



It should be further noted that the values for each entry were not adjusted for the applicable years, mainly because escalators were not available for all samples. The "oldest" data point is for 2011, so adjustments for inflation would not likely be significant.

Although this study did not explore the reasons for the differences between utility avoided costs, it is difficult to correlate relative values with overall utility retail rates or method of calculation. There can certainly be other factors that drive avoided T&D cost calculations. This is just to say that it is difficult to generalize and points out that there is a large amount of variability in estimated costs.

E. Conclusion

This study sought to investigate different ways that utilities in the United States estimated avoided transmission and distribution costs for energy efficiency cost-effectiveness evaluations that could inform its next DSM plan. The survey of methodologies and benchmarking determining that there are a variety of ways to estimate such values and a very broad range of estimates among the 35 utilities included. Given the dynamic state of the methodologies used to develop these estimates it is recommended that PSCo periodically revisit this issue and update the survey of current estimates and the methodologies used.

Appendix A – Selection of Approaches to Calculating Avoided T&D Costs

Method	Brief Description	Examples	Strengths	Weaknesses
System Planning Approach	• Uses costs and load growth for specific T&D projects based on a system planning study	• Vermont Electric Company (2003) – focused on specific transmission upgrade	• Potentially more accurate • Uses specific project data to develop estimates • Forces consideration of DER effects on project-by-project basis	• Costly and time consuming • May not be appreciably more accurate than other approaches • Dependent upon individual projects included in analysis
Mix of Historical and Forecast Information	• Uses data on historical and forecast T&D investments, determines what's related to load growth, and weights the historical and forecast contributions	• ICF Tool used in the Northeast, Vermont DPS variation	• Uses publicly available FERC Form 1 data • Easily calculated and updated • Uses a form of marginal costs • Addresses "lumpiness" of T&D investments • Used by multiple other states • Relies upon historical as well as forecast information	• Assumes it's possible to differentiate amount of T&D investment that corresponds to load growth rather than maintenance, reliability and customer growth • Does not incorporate variability associated with time/location differences • Can't readily handle low forecast growth
Current Values	• Develops average cost to serve existing load by dividing each system's net cost	• MidAmerican Energy (IA, IL, SD), Commonwealth Edison (IL)	• Uses publicly available FERC Form 1 data • Easily calculated and updated	• May tend to undervalue • Does not incorporate variability associated with time/location differences

Method	Brief Description	Examples	Strengths	Weaknesses
Rate case marginal cost data with allocators	• Uses T&D marginal cost of service data from utility rate cases and apply time and locational factors related to weather or specific substation loadings	• California IOUs	• Uses publicly available data (rate case portion) • Uses approach consistent with ratemaking • Uses time and location differentiated data • Uses marginal cost information	• Potentially costly and time consuming • May not be appreciably more accurate than other approaches • Somewhat assumes use of hourly avoided costs for Generation • Requires estimation of investments deferred by EE
Rate case marginal cost data	• Use T&D marginal cost of service data from most recent rate case	• Ameren (MO), PacifiCorp (OR, UT, WA), Nevada Energy, Consolidated Edison (NY)	• Uses publicly available data • Is approach consistent with ratemaking • Uses marginal cost information	• May not be appreciably more accurate than other approaches • Requires estimation of investments deferred by EE
IRP Method	• Uses without and without EE runs to determine avoided transmission costs	• Tucson Electric Power	• Is consistent with integrated resource plan	• Is highly dependent on IRP's model ability to calculate transmission costs • Requires integrated resource plan • Only updated as frequently as resource plan • Typically can only provide transmission
Averaging method	• Take simple average of a selection of similar	• Wisconsin Focus on Energy Market Potential Study (used Iowa)	• Uses publicly available data • Very easily calculated	• Must pick appropriate proxy utilities for averaging

Method	Brief Description	Examples	Strengths	Weaknesses
	jurisdictions	• Northwest Conservation and Electric Power Plan (used 8 utilities)		• Not specific to one utility
Simple Method	• Take representative sample of recent T&D upgrade projects, divide by increased capacity and annualize	• Unknown	• Very simple • Provides real information from specific example • Can be done for transmission, distribution and sub-transmission	• Project may not be system representative • Must still determine what portion of increased capacity relates to load growth

Appendix B – Survey of Utility Avoided Transmission and Distribution Costs

Estimated Values

State	Utility	Date of Estimate	Transmission	Distribution	O&M	Total T&D	Units
AZ	TEP	2013	N/A	N/A		$100.00	$/kW-year
AZ	APS	2013	$0	$0		$0	
CA	PG&E-Com	2011	$19.60	$55.97		$75.57	$/kW-year
CA	PG&E-Res	2011	$18.77	$55.85		$74.62	$/kW-year
CA	SCE-Com	2011	$23.39	$30.10		$53.49	$/kW-year
CA	SCE-Res	2011	$23.39	$30.10		$53.49	$/kW-year
CA	SDG&E-Com	2011	$21.08	$52.24		$73.32	$/kW-year
CA	SDG&E-Res	2011	$21.08	$52.24		$73.32	$/kW-year
CA	Weighted Average	2011	$21.20	$44.38		$65.59	$/kW-year
CT	CL&P	2013	$1.30	$30.94		$32.24	$/kW-year
CT	United Illuminating	2013	$2.64	$47.82		$50.46	$/kW-year
ID	Idaho Power	2014	$0	$0		$0	
IA	Interstate Power & Light	2014	$81.00	$26.00		$107.00	$/kW-year
IA	MidAmerican	2013	$14.85	$37.01		$51.86	$/kW-year
IL	Commonwealth Edison	2014	N/A	N/A		$42.00	$/kW-year
MA	National Grid	2013	$88.64	$111.37		$200.01	$/kW-year
MA	NSTAR	2011	$21.00	$68.79		$89.79	$/kW-year
MA	WMeco	2011	$22.27	$76.08		$98.35	$/kW-year
MA	Unitil	2013	$0	$171.15		$171.15	$/kW-year
MI	Consumer's Energy	2012	$0	$0		$0	
MN	Xcel	2014	$14.31	$38.85		$53.17	$/kW-year
MO	Ameren	2014	$22.00	$10.00		$32.00	$/kW-year
NH	PSNH	2013	$16.70	$53.35		$70.05	$/kW-year
NW	NW Conservation and Electric Power Plan utilities	2010	$0	$23.00		$66.59	$/kW-year

State	Utility	Date of Estimate	Transmission	Distribution	O&M	Total T&D	Units
NV	Sierra Pacific Power dba Nevada Energy	2013	N/A	N/A		$12.23	$/kW-year
NY	Consolidated Edison (Network)	2013	$0	$120.52		$120.52	$/kW-year
NY	Consolidated Edison (Non-Network)	2013	$0	$42.63		$42.63	$/kW-year
OR	PacifiCorp	2011	$36.89	$15.75		$52.64	$/kW-year
OR	PGE	2011	$10.80	$22.40		$33.20	$/kW-year
RI	National Grid	2013	$20.62	$20.62		$41.24	$/kW-year
SD	MidAmerican	2012	$13.79	$34.37		$48.16	$/kW-year
UT	PacifiCorp	2011	$36.89	$15.75		$52.64	$/kW-year
VT	Burlington Electric Department (Prescriptive Programs)	2013	N/A	N/A		$158	$/kW-year
VT	Burlington Electric Department (Custom Programs)	2013	N/A	N/A		$48	$/kW-year
VT	Efficiency Vermont	2013	$34.25	$93.25	$50.00	$158.15	$/kW-year
WA	PacifiCorp	2011	$36.89	$15.75		$52.64	$/kW-year
WI	Focus on Energy		$0	$0		$0	

N/A refers to instances where the utility did not break out the individual transmission and distribution values.

Methods and Data Sources

State	Utility	Method	Data Source for Calcs	Notes
AZ	TEP	Calculated avoided G&T using IRP. Developed $/kW-year based on G&T costs avoided by selected DSM portfolio.	IRP	TEP considers the avoided capacity costs confidential as part of their Resource Plan. They do not provide detail in their EE Plan beyond the SCT (Societal Cost Test). Not included in averaging calcs.
AZ	APS			Does not specifically incorporate an avoided capacity value for T&D. Includes line losses for energy and capacity.
CA	PG&E-Com	The costs taken from utility rate case filings are used as a reasonable proxy for the long-run marginal cost T&D investment that is avoided over time with the addition of distributed energy resources.	General Rate Case	Only included PG&E Com/Res average in averaging calcs and graphs.
CA	PG&E-Res			
CA	SCE-Com		FERC Form 1	Only included one SCE in averaging calcs and graphs.
CA	SCE-Res		FERC Form 1	
CA	SDG&E-Com	The costs taken from utility rate case filings are used as a reasonable proxy for the long-run marginal cost T&D investment that is avoided over time with the addition of distributed energy resources.	General Rate Case	Only included one SDG&E in averaging calcs and graphs.
CA	SDG&E-Res			They are the same values used for the 2011 CEC California Building Energy Standards, and the CPUC CSI and DR proceedings.
MN	Xcel		Internal	
CT	CL&P	ICF Tool	FERC Form 1	
CT	United Illuminating	Black & Veatch Report		United Illuminating Avoided Transmission & Distribution Cost Study Report, Black & Veatch, September 2009.
IA	Interstate Power & Light		MISO Att. O for T.	
IA	MidAmerican	The average cost to serve existing load is calculated for both the transmission and distribution systems by dividing each system's net cost by each system's peak capability. MidAmerican's Federal Energy Regulatory Commission (FERC) Form 1 data is used to calculate the net costs of the transmission	FERC Form 1	Iowa EE rules do not required avoided T&D. Is done as an alternative calculation - rules dictate use of a CT for avoided capacity costs and provides the formula. Ratepayer advocates currently advocating for use of MISO Attachment O rates for avoided transmission

State	Utility	Method	Data Source for Calcs	Notes
		and distribution systems by taking MidAmerican's original cost of plant less accumulated depreciation for each respective system. MidAmerican T&D avoided costs are calculated using depreciated original cost figures listed in FERC Form 1.		(Docket INU-2014-0001)
IL	Commonwealth Edison	ComEd conducted an updated analysis to place a value on the avoidance or deferral of new transmission and distribution capacity as a result of energy efficiency. The most recent analysis determined that an avoided T&D cost of $42/yr. is appropriate for cost-effectiveness analysis.		8-27-14: The avoided T&D cost is from an internal study and does not have a breakdown between T and D.
MA	National Grid	ICF Tool	FERC Form 1	
MA	NSTAR	ICF Tool	FERC Form 1	
MA	WMeco	ICF Tool	FERC Form 1	
MA	Unitil	ICF Tool	FERC Form 1	
MI	Consumer's Energy			*While the cost of building transmission and distribution systems -- by either building with less capacity or avoiding building completely – theoretically might be avoided, Consumers Energy's current transmission and distribution systems are typically adequate to meet customers' needs. The current situation, relative to numbers of customers and demand, would need to substantially change before costs of building transmission and distribution systems could be avoided.*
MN	Xcel		Internal	
MO	Ameren	Rate case marginal costs	2010 Rate Case	
NH	PSNH	ICF Tool	FERC Form 1	
NW	NW Conservation and Electric Power Plan utilities	Used benchmarked data to come up with "representative" value. Estimated a value of $25 for transmission, but did not adopt. See notes.	Regional Technology Forum (RTF)	Is part of 6th 5-year Power Plan. Planning for 7th began in 2014. "The Council adopted the RTF recommended value for distribution system avoided cost. However, because the value of avoiding the transmission system investments is

State	Utility	Method	Data Source for Calcs	Notes
				already included in the wholesale market prices produced by the AURORA model the Council did not use the RTF estimate of the benefits of deferring transmission system expansion so as to avoid double counting." (p. E-14).
NV	Sierra Pacific Power dba Nevada Energy	Is the annual revenue requirement for T&D impacted by EE. Submitted as marginal cost study with rate case. 13-06002	Rate case T&D costs	Uses "conservative value" of 25% of T&D revenue requirements of $49.92 (was $47.50 in 2010 rate case). Does not account for distribution costs beyond the substation. Uses "PortfolioPro" cost benefit model developed for them by Cadmus. However, in IRP NVEnergy recognizes that its T&D costs are low based on Synapse's best practices study.
NY	Consolidated Edison (Network)	Marginal costs associated with load growth	Utility marginal cost data	Study developed in response to requirement from NY Public Service Commission. Network resources are associated with underground low-voltage distribution systems such as in downtown NYC. Emergence of T avoided costs do not occur until 2017.
NY	Consolidated Edison (Non-Network)	Marginal costs associated with load growth	Utility marginal cost data	Study developed in response to requirement from NY Public Service Commission. Non-Network resources are associated with radial distribution systems. Emergence of T avoided costs do not occur until 2017.
OR	PacifiCorp	Regulation Department provides as input to the IRP. Represents "an average of the values from a marginal cost of service study from the company's last 5 general rate cases for demand-related substation and transmission costs."	Rate case T&D revenue requirements	The resource deferral fixed cost benefit is comprised of the deferred capital recovery and fixed operation and maintenance costs of a "next best alternative" resource—a combined- cycle combustion turbine (CCCT).
OR	PGE	ICF Tool	FERC Form 1	
RI	National Grid	ICF Tool	FERC Form 1	
SD	MidAmerican	Avoided distribution costs are calculated by determining the economic carrying charge associated with MidAmerican's net distribution investment on a $/kW basis; Avoided transmission capacity costs are calculated by determining the economic carrying charges associated with MidAmerican's net transmission investment on a	FERC Form 1 and utility discount rates	Same values as Iowa and, therefore, not duplicated in averaging calcs

State	Utility	Method	Data Source for Calcs	Notes
		$/kW basis, where kW refers to the total transmission system capacity.		
UT	PacifiCorp	See OR		Same values as Oregon, and, therefore, not duplicated in averaging calcs
VT	Burlington Electric Department (Prescriptive Programs)			Different values for prescriptive and custom programs. Prescriptive values decline over time. Is 2012 $. Order on 12/13/2012 in Docket EEU-2011-02
VT	Burlington Electric Department (Custom Programs)	VT Department of Public Service adapted ICF Tool. Method used by AESC 2013, applicable to Vermont.		
VT	Efficiency Vermont	VT Department of Public Service adapted ICF Tool. Method used by AESC 2013, applicable to Vermont.		The statewide estimates are based on load-related investments in the last decade for which Vermont experienced significant load growth, ending in 1996. Adds O&M and then subtracts a "T&D offset". Order on 12/13/2012 in Docket EEU-2011-02, See values below through 2040
WA	PacifiCorp	See OR		Same values as Oregon and, therefore, not duplicated in averaging calcs
WI	Focus on Energy	$-	$-	Does not currently include avoided T&D in FOE cost effectiveness evaluations. Discussed possibility but felt that the effort would require considerable analysis to determine what was avoided. Uses MISO forecasted LMPs as primary energy avoided costs (no capacity apparently). But LMPs theoretically incorporate all (G, T&D). ECW 2009 market potential study incorporate $30/kW-year value in its analysis based on Iowa utilities' calculations.

Row		Value	Source
1	Tx Peak (MW)	14,355	2016 FERC Form 1
2	Peak (MW)	13,248	2016 FERC Form 1
3	Tx Year End Balance ($)	2,482,661,395	2016 FERC Form 1
4	Depreciation ($)	40,048,151	2016 FERC Form 1
5	Net Tx Year End Balance ($)	2,442,613,244	Row3 - Row4
6	Net Tx Balance ($/kW)	170.16	(Row5 / Row3) / 1000
7	Solar Summer Capacity Credit	44%	DEP 2017 IRP p 22
8	Solar Winter Capacity Credit	5%	DEP 2017 IRP p 22
9	Estimated Solar Capacity Factor	16.8%	PV Watts, Florence, SC
10	Summer Avoided Tx Value due to PV ($/kWh)	0.050851	(Row6 x Row7)/(8760 x Row9)
11	Winter Avoided Tx Value due to PV ($/kWh)	0.005778	(Row6 x Row8)/(8760 x Row9)